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A NEW THEORY OF THE SUSPENSION SYSTEM WITH STIFFENING TRUSS.

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(Continued from page 133.)

BEST RATIO OF HEIGHT OF TRUSS TO VERSINE OF CABLE.

The deflection of the cable at the centre is, then, from (16),

$$\Delta_1 = \frac{3}{4}\lambda_1 \frac{l^2}{v} \qquad (21)$$

where $\lambda_1 = \frac{H}{E_1 F_0}$ and F_0 is the cross-section due to strain at ends.

The deflection at the centre of a beam, fixed horizontally at both ends, when the beam is uniformly loaded with the load m per unit of length, is

$$\Delta_2 = \frac{m l^4}{24 E_2 I_2}$$

For a braced girder we may take the radius of gyration equal to $\frac{h}{2}$, when h is the depth of girder. Hence $I_2 = \frac{F_2 h^2}{4}$ where F_2 is the total cross-section of both the flanges at the centre. We have, then,

$$\Delta_2 = \frac{m\,l^4}{6\,E_2 F_2 h^2}$$

If we take moments about the centre of the span, we have for the strain in either flange, since the moment at the centre is $\frac{m\,l^2}{6}$,

$$\text{Strain} = \frac{m\,l^2}{6\,h}$$

From (III), then,

$$\lambda_2 = \frac{S}{\frac{F}{2}E_2} = \frac{m\,l^2}{3E_2F_2h}$$

We have then

$$\Delta_2 = \frac{1}{2}\,\lambda_2\,\frac{l^2}{h} \qquad (22)$$

Equating (22) and (21), we obtain for the best ratio of height of truss to versine of cable,

$$\frac{h}{v} = \frac{2}{3}\,\frac{\lambda_2}{\lambda_1} \qquad (V)$$

Since the cable is always in tension we can take a higher unit strain for it than for the truss, even when they are of the same material. If of wire, the unit strain may be considerably greater than the unit strain in the truss. Moreover, the tops of the towers may give somewhat, and this has the same effect as an increase of λ_1.

Example.—Let the material in cable and truss be wrought iron. Take the coefficient of elasticity at say 24,000,000 pounds per square inch, or 12,000 tons. If, then, we assume the safe unit strain for the truss 4 tons, and for the cable, if of wire, 7 tons per inch, we have

$$\lambda_1 = \frac{S}{F_1E_1} = \frac{7}{12000} \text{ and } \lambda_2 = \frac{S}{F_2E_2} = \frac{4}{12000}$$

We have, then, from (V),

$$\frac{h}{v} = \frac{2}{3} \times \frac{4}{7} = \frac{8}{21} = 0{\cdot}4 \text{ nearly.}$$

In a similar manner we can find $\frac{h}{v}$ in any special case.

Load Due to Change of Temperature.

A fall of temperature causes the cable to shorten. The effect of this is the same as a uniform upward load over the truss and an equal

downward load over the cable. Let this load be equivalent to q per unit of length. We may call q the unit "cold load." This load pulls the truss up and acts as a downward load, therefore, on the cable. The actual rise at the centre of cable is, then, the rise due to change of length, minus the deflection due to cold load.

The rise due to change of length is, from (16), $\frac{3}{4}\ \varepsilon\ t\ \frac{l^2}{v_1}$. The horizontal tension at centre of cable, due to load q, per unit of length is, approximately, since in this case v and v_1 are nearly equal, $H = \frac{q\ l^2}{2\ v_1}$. The elongation at centre due to this tension is, for constant cross-section, F_0, from (III)

$$\lambda_1 = \frac{H}{E_1 F_0} = \frac{q\ l^2}{2\ v_1 E_1 F_0}$$

where F_0 is the cross-section due to the strain *at ends*.

The deflection corresponding to this elongation is from (16)

$$\frac{3}{4}\ \frac{q\ l^2}{2\ v_1 E_1 F_0}\ \frac{l^2}{v_1} = \frac{3\ q\ l^4}{8\ v_1^2 E_1 F_0}$$

The actual rise of the cable is, then, at centre

$$\Delta_1 = \frac{3}{4}\ \varepsilon\ t\ \frac{l^2}{v_1} - \frac{3\ q\ l^4}{8\ v_1^2 E_1 F_1}$$

The upward deflection of the truss at the centre is

$$\Delta_2 = \frac{q\ l^4}{24\ E_2\ I_2}$$

or putting $I_2 = \frac{F_2 h^2}{4}$,

$$\Delta_2 = \frac{q\ l^4}{6\ E_2 F_2 h^2}$$

Equating these two deflections, we obtain

$$q = \frac{2\ \varepsilon\ t\ E_1 F_0\ v_1}{l^2\left(1 + \frac{4\ E_1 F_0 v_1^2}{9\ E_2 F_2 h^2}\right)} \qquad \text{(VI)}$$

From this equation we can find the temperature load q, or that unit load which would give the same strains as are caused by change of temperature.

For a fall of temperature, this load, or the "cold load," is carried

by the cable, and bends the girder upwards. For a rise of temperature, the "hot load" is carried by the truss alone.

The strains in each case must be combined with those caused by the dead and live loads, in such a way as to give the greatest strains which can ever occur.

Example.—If we take as before, $\varepsilon t = \frac{1}{2000}$ and assume $E_1 = E_2$, $\frac{h}{v} = \frac{1}{3}$ and $\frac{F_0}{F_2} = \frac{1}{2}$, we have, taking $E_1 = E_2 = 12{,}000$ tons per sq. inch, $l = 400$ feet, $v = 50$ feet and $F_0 = 200$ sq. inches, from (VI)

$$q = 0{\cdot}25 \text{ ton per foot.}$$

as the load on cable for fall of temperature, or the load on truss for rise of temperature.

Live Load over Entire Span.

Let the live load m per unit of length cover the entire span. A portion of this load acts as a uniform load upon the cable, and a portion as a uniform load upon the truss. Let $n\,m$ be the portion carried by the cable. Then $(1 - n)m$ is the load of the truss. We have from (18a) for the deflection of cable at centre,

$$\Delta_1 = \frac{3nml^4}{8E_1F_0v_1v}.$$

The deflection of the truss is

$$\Delta_2 = \frac{(1-n)ml^4}{24E_2I_2},$$

or putting $I_2 = F_2\frac{h^2}{4}$ where h is the depth of truss,

$$\Delta_2 = \frac{(1-n)ml^4}{6E_2F_2h^2}.$$

Equating these two deflections, we obtain

$$n = \frac{1}{1 + \frac{9}{4}\frac{E_2F_2h^2}{E_1F_0v_1v}} \qquad \text{(VII)}$$

Partial Uniform Load.

Under the action of a partial load which extends only over a portion of the span, the curve of the cable is no longer a parabola, and the

greatest deflection is no longer at the centre. As the office of the truss is to prevent deformation, it acts to distribute the partial load over the cable. But as the curve of the cable is no longer parabolic, the distributed load cannot be regarded as uniform, and, in fact, is not uniform.

If we suppose, however, that the cable load is uniform, we can easily find that portion of the partial load which would act, in such case, upon the cable as a uniform load. Although the supposition is not correct, we shall have future use for this result, and we therefore deduce it here.

Suppose a partial load m per unit of length, to extend over a distance a *from each end.* These two loads being equal and symmetrically placed, will cause a uniform load over the cable, the curve of which is therefore still a parabola. Of the whole load $2ma$, let the amount $2km$ act as a uniform load per unit of length on the cable, km being the unit load due to *each partial load.*

Then the deflection of the cable at the centre is from (19a)

$$\Delta_1 = \frac{6kml^4}{8E_1F_0v_1v}.$$

The deflection of the truss at centre is equal to the deflection which would be caused by the two weights acting alone, minus the upward deflection due to the reaction of cable, or the upward load on the truss.

The first deflection, putting $I_2 = F_2\frac{h^2}{4}$, is

$$\frac{m}{6E_2F_2h^2}[2la^3 - a^4].$$

The second deflection is

$$\frac{2kml^4}{6E_2F_2h^2}.$$

The actual deflection of the truss at the centre, is then

$$\Delta_2 = \frac{m}{6E_2F_2h^2}[2la^3 - a^4] - \frac{2kml^4}{6E_2F_2h^2}.$$

Equating Δ_1 and Δ_2, we obtain

$$k = \frac{2la^3 - a^4}{2l^4\left[1 + \frac{9E_2F_2h^2}{4E_1F_0v_1v}\right]} \qquad \text{(VIII)}$$

This equation gives the value of k for any value of a from 0 to l. If the load extends from the left end *beyond* the centre, we have

$$k = \frac{2l^4 - a(2l-a)^3}{2l^4\left[1 + \frac{9}{4}\frac{E_2F_2h^2}{E_1F_0v_1v}\right]} \qquad \text{(VIII}a\text{)}$$

In either of these equations, when $a = l$, the value of k becomes equal to half of n as given by (VII) as should be. For varying cross-section of cable, put F_1 for F_0.

Approximate Values of F_0, F_1 and F_2.

The use of the equations thus far deduced requires that F_0 and F_2, the cross-sections at end of cable and centre of truss, should be known. But these are the very quantities which are to be found. It is therefore necessary to make a preliminary, if not very exact, estimate of these cross-sections, before we can use our formulæ. The strains being then found, we can determine the corresponding cross-sections. If they do not agree well enough with their assumed values, a second approximation can be made.

We see from (VI), (VII) and (VIII), that very considerable variations in the ratio $\frac{F_2}{F_0}$, will have but slight effect upon the resulting values of q, n and k. Our approximation need not then be very exact.

We may suppose the cable to carry the load $p + m$ per unit of length. This is an error in excess, because really the cable carries only a portion of the live load m. The "cold load" q, however, which, for the present, we neglect, tends to balance this error. We may also take $v = v_1$.

The horizontal tension at centre of cable would then be approximately

$$H = \frac{(p+m)l^2}{2v}.$$

The secant of the angle of inclination at the ends would be from (11)

$$\frac{ds}{dx} = 1 + \frac{2v^2}{l^2}.$$

Hence, the strain at the ends is

$$S_0 = \frac{(p+m)l^2}{2v}\left(1 + \frac{2v^2}{l^2}\right).$$

Let the greatest allowable unit strains for the cable be f_1, then

$$\text{approx. } F_0 = \frac{S_0}{f_1} = \frac{(p+m)l^2}{2vf_1}\left(1+\frac{2v^2}{l^2}\right) \qquad \text{(IX)}$$

From equation (IX) we can compute approximately the cross-section F_0 at the ends of cable, or the constant cross-section of cable.

The cross-section F_1 at the centre of the cable, if the cross-section varies with the strain is also approximately

$$\text{approx. } F_1 = \frac{H}{f_1} = \frac{(p+m)l^2}{2vf_1} \qquad \text{(IX}a\text{)}$$

We may also find a preliminary value of n, by putting $\frac{F_2}{F_0} = 1$ and $v_1 = v$ in equation (VII). We have then approximately

$$\text{approx. } n = \frac{1}{1+\frac{9E_2h^2}{4E_1v^2}} \qquad (23)$$

We can now find the preliminary value of q by putting $\frac{F_0}{F_2} = 1$ in (VI). Thus

$$\text{approx. } q = \frac{2\varepsilon t E_1 F_0 v}{l^2\left(1+\frac{4E_1v_2}{9E_2h^2}\right)} \qquad (24)$$

For varying cross-section put F_1 in place of F_0.

We can now compute an approximate value for F_2.

Thus we may consider the truss loaded with $(1-n)m+q$ per unit of length, where q is the "hot load." The moment at centre of truss is then

$$\frac{[(1-n)m+q]l^2}{6}$$

The strain in each flange at the centre is then

$$\frac{[(1-n)m+q]l^2}{6h}$$

The total area of both flanges at the centre is then, if f_2 is the greatest allowable unit strain for truss,

$$\text{approx. } F_2 = \frac{[(1-n)m+q]l^2)}{3hf_2} \qquad \text{(X)}$$

Equations (IX) (IXa), (23) (24 and (X) give us approximations to the values of F_0, F_1 and F_2 sufficiently exact for our purpose.

Greatest Deflection and Strain in the Cable.

We can now find the strain at any point of the cable.

The greatest strain in the cable will occur when the dead load, live load and temperature load, all act. The uniform load of the cable then will be $p+nm+q$. The dead load p per unit of length and the live load m per unit of length are supposed to be known. We can find n and q from (VII) and (VI) with the aid of (X) and (IX).

The deflection at the centre then of cable is from (IV).

$$\Delta_1=\frac{3(p+nm+q)l^4}{8E_1F_0v_1v} \qquad \text{(XI)}$$

For varying cross-sections we must put F_1 in place of F_0 in all formulæ. The new versine v_1 is given by (14.) It will in general be so nearly equal to v that small error will be committed by taking them equal.

The greatest horizontal tension at centre of cable is then

$$H=\frac{(p+nm+q)l^2}{2v_1} \qquad \text{(XII)}$$

The strain at any point is H sec. i, where i is in the angle of inclination of cable at that point to horizontal. From (11) we have

$$\text{sec. } i=\frac{ds}{dx}=1+\frac{2v_1^2x^2}{l^4}$$

Hence the strain at any point is

$$S=\frac{(p+nm+q)l^2}{2v_1}\left(1+\frac{2v_1^2x^2}{l^4}\right) \qquad \text{(XIII)}$$

where x is the distance of point from centre. If the cross-section is constant, it must be determined from the greatest strain, or making $x=l$ in (XIII). We have then the constant cross-section.

$$F_0=\frac{S_{x=1}}{f_1}=\frac{(p+nm+q)l^2}{2v_1f_1}\left(1+\frac{2v_1^2}{l^2}\right) \qquad \text{(XIV)}$$

If the cross-section varies, the cross-section at the centre is

$$F_1=\frac{H}{f_1}=\frac{(p+nm+q)l^2}{v_1f_1} \qquad \text{(XV)}$$

These cross-sections thus found ought to agree satisfactorily with our approximate values found from (X) and (IX). If they do not, another and better approximation can be made.

We can thus easily find the deflection at the centre and the strain at

any point, whether the cross-section is constant or varies according to the strain.

A discussion of the side spans, if any, is unnecessary so far as the cable is concerned. If the cable is of uniform cross-section it must evidently remain of the same cross-section for the side spans also. If it varies in cross-section, it will be sufficient to make the area of the cable at any point in the side span equal to its area at the corresponding point of the centre span, whatever the length of the side span.

Estimate of the Dead Weight.

In any given case, n and q are given by (VII) and (VI). We also know m or the unit live load. But p, or the unit dead load, depends upon the weight of the truss and cable, or upon F_0 or F_1 and F_2, and these are the very quantities it is required to determine. We must therefore make a preliminary estimate of the unit dead load p. The dead load consists of the weight of the floor system and wind bracing, etc., the weight of the cable and the weight of the truss. Of these, the weight of floor system, wind bracing, etc., can be very exactly estimated for any special case and system. The weight of cable can be easily estimated from (IX) and (IXa). Thus if the cross-section of cable is uniform, the cubic contents of cable are

$$F_0 s_1 = 2F_0 l\left(1+\frac{2v_1^2}{3l^2}\right) \tag{25}$$

where v_1 is given by (14).

This multiplied by the weight of a cubic unit of cable which is known of course, will give the weight of cable. We may take this weight as uniformly distributed and add it to weight of floor system, etc.

If cross-section of cable varies, it will be near enough to take the mean area, or $\frac{F_1+F_0}{2}$, and multiply by the length or

$$\frac{F_1+F_0}{2}\, s_1 = (F_1+F_0)l\left(1+\frac{2v_1^2}{3l^2}\right) \tag{26}$$

Lastly, for the weight of truss, we have for the cubic contents of the flanges $2F_2 l$, assuming that the flanges are constant. This multiplied by the weight of a cubic unit of the material of the truss will give an estimate of weight of girder. As the flanges are not uniform in cross-section, the estimate is too large. But the error in this direction is balanced by the weight of bracing, which we neglect.

We can thus estimate p closely enough for our purposes. The strains in the cable can then be found.

Recapitulation of Formulæ Necessary for Calculation of Cable.

For convenience of reference, let us now group together the formulæ thus far deduced, in the order required for calculation.

We have for the best ratio of height of truss to versine of cable

$$\frac{h}{v} = \frac{2\lambda_2}{3\lambda_1} = \frac{2f_2}{3E_2\frac{f_1}{E_1}} \tag{V}$$

For preliminary estimate, we have next

$$\text{approx. } n = \frac{1}{1+\frac{9E_2h^2}{4E_1v^2}} \tag{23}$$

$$\text{approx. } F_0 = \frac{(p+m)l^2}{2vf_1}\left(1+\frac{2v^2}{l^2}\right) \tag{IX}$$

$$\text{approx. } F_1 = \frac{(p+m)l^2}{2vf_1} \tag{IXa}$$

$$\text{approx. } q = \frac{2\varepsilon t E_1 F_0 v}{l^2\left(1+\frac{4E_1v^2}{9E_2h^2}\right)} \tag{24}$$

$$\text{approx. } F_2 = \frac{[(1-n)m+q]l^2}{3hf_2} \tag{X}$$

These approximate values being thus determined, we have

$$v_1 = v\left[1+\frac{\lambda_1}{2}\left(1+\frac{3l^2}{2v^2}\right)\right] \tag{14}$$

where $\lambda_1 = \frac{f_1}{E_1}$ when the cross-section of cable varies according to the strain, and $\lambda_1 = \frac{F_1}{F_0}\frac{f_1}{E_1}$ when the cross-section of cable is constant.

We have now the accurate value

$$n = \frac{1}{1+\frac{9E_2F_2h^2}{4E_1F_0v_1v}} \tag{VII}$$

where we put for F_2 and F_0 their approximate values as determined by

(X) and (IX). For varying cross-section of cable, we put F_1 in place of F_0. For a fall of temperature of t^0 below the mean, the uniform "cold load" of cable per unit of length is

$$q = \frac{2\epsilon t E_1 F_0 v_1^2}{l^2\left[1+\frac{4E_1F_0v_1^2}{9E_2F_2h^2}\right]} \qquad \text{(VI)}$$

For varying cross-section of cable, put F_1 in place of F_0. For rise of temperature, q is the "hot load" of truss.

For a partial distributed load, ma, covering a distance, a, from the left end, upon the supposition that the curve of the cable remains a parabola, with the vertex at the centre, the equivalent uniform load on the cable per unit of length is, when a is less than the half-span or when $a < l$

$$k = \frac{a^3(2l-a)}{2l^4\left[1+\frac{9E_2F_2h^2}{4E_1F_0v_1v}\right]} \qquad \text{(VIII)}$$

when $a > l$

$$k = \frac{2l^4-a(2l-a)^3}{2l^4\left[1+\frac{9E_2F_2h^2}{4E_1F_0v_1v}\right]} \qquad \text{(VIII}a\text{)}$$

For the deflection due to a uniform load, u, per unit of length, we have

$$\delta_1 = \frac{3ul^2}{8E_1F_0v_1v}(l^2-x^3) \qquad \text{(IV)}$$

where x is the distance of the point from the centre.

For varying cross-section of cable, always put F_1 in place of F_0.

For the maximum deflection at the centre of cable,

$$\Delta_1 = \frac{3(p+nm+q)l^4}{8E_1F_0v_1v} \qquad \text{(XI)}$$

For varying cross-section put F_1 in place of F_0.

The greatest horizontal strain at centre of cable is now

$$H = \frac{(p+nm+q)l^2}{2v_1} \qquad \text{(XII)}$$

The strain at any point of cable, distant x from centre is

$$S = \frac{(p+nm+q)l^2}{2v_1}\left(1+\frac{2v_1^2x^2}{l^4}\right) \qquad \text{(XIII)}$$

The constant cross-section of cable is

$$F_0 = \frac{(p+nm+q)l^2}{2v_1 f_1}\left(1+\frac{2v_1^2}{l^2}\right) \qquad \text{(XIV)}$$

The cross-section at centre, if cross-section varies with the strain, is

$$F_1 = \frac{(p+nm+q)l^2}{2v_1 f_1} \qquad \text{(XV)}$$

Example.—Take, for instance, the Niagara bridge, the span of which $2l = 800$ feet, $v = 60$ feet. Take $E_1 = E_2 = 12{,}000$ tons per sq. inch, and let the greatest allowable strain in the cable be $f_1 = 10$ tons and in the truss $f_2 = 4$ tons per sq. inch. Take $e = 0{\cdot}00000686$ for one degree Fahr. and let $t = 70°$ above or below the mean temperature of erection. Then $et = \frac{1}{2000}$.

Let also $m = 1$ ton per foot and estimated $p = 0{\cdot}5$ ton per foot.

Then from (V) we have for best height of truss

$$h = \frac{2\times 4\times 60}{3\times 12000\times\frac{10}{12000}} = 16 \text{ feet.}$$

From (23) we obtain

$$\text{approx. } n = \frac{1}{1+\frac{9\times 256}{4\times 3600}} = 0{\cdot}9 \text{ nearly.}$$

We have also from (IX) and (IXa)

$$\text{approx. } F_0 = \frac{1{\cdot}5\times 160000}{2\times 60\times 10}\left(1+\frac{2\times 3600}{160000}\right) = 209 \text{ sq. inches.}$$

$$\text{approx. } F_1 = \frac{1{\cdot}5\times 160000}{2\times 60\times 10} = 200 \text{ sq. inches.}$$

We can now estimate from (24)

$$\text{approx. } q = \frac{2\times\frac{1}{2000}\times 12000\times 209\times 60}{160000\left(1+\frac{4\times 3600}{9\times 256}\right)} = 0{\cdot}055 \text{ ton per foot.}$$

From (X) we have

$$\text{approx. } F_2 = \frac{(0{\cdot}05+0{\cdot}055)160000}{3\times 16\times 4} = 133 \text{ sq. inches.}$$

We have also from (14), since λ_1 for constant cross-section is $\frac{200\times 4}{209\times 12000}$ or $\lambda_1 = \frac{1}{3135}$

$$v_1 = v\left[1+\frac{1}{6270}\left(1+\frac{3\times 160000}{2\times 3600}\right)\right] = 1{\cdot}01v.$$

We may, therefore, take $v_1 = v$ without appreciable error.

We have next from (VII)

$$n = \frac{1}{1+\frac{9\times133\times256}{4\times209\times3600}} = 0{\cdot}9 \text{ ton per foot,}$$

or about the same as our first estimated value.

From (VI) we have then

$$q = \frac{2\times\frac{1}{2000}\times12000\times209\times60}{160000\left(1+\frac{4\times209\times3600}{9\times133\times256}\right)} = 0{\cdot}04.$$

We have then for constant cross-section of cable, from (XIV),

$$F_0 = \frac{(0{\cdot}5+0{\cdot}9+0{\cdot}04)160000}{2\times60\times10}\left(1+\frac{2\times3600}{160000}\right) = 209 \text{ sq. inches.}$$

or the same as our estimated value. For the given unit strain, this would require 4 cables of 8 inches each in diameter.

From (X), finally, we have for the deflection of cable at the centre,

$$\Delta_1 = \frac{3\times1{\cdot}5\times160000}{8\times12000\times209\times3600} = 1{\cdot}5 \text{ feet.}$$

(To be continued.)

New Determination of the Electric Ratio.—Prof. Stoletow, of the University of Moscow, has made some recent experiments in order to determine Maxwell's ratio between the electromagnetic and electrostatic units. The electrostatic capacity, c, of a condenser formed of two plates with plain and parallel faces is equal to $\frac{S}{4\pi\delta}$, S being the surface and δ the distance between the plates. The electromagnetic capacity is $\frac{c}{v^2}$. The condenser is charged and the discharge is received by a galvanometer; by producing 100 discharges per second the galvanometer receives a permanent deviation, from which the value of v can be determined. Stoletow's results accord very closely with those which have been previously ascertained, indicating a velocity between 298,000 and 300,000 km. (185,170 to 186,410 miles) per second.—*Soc de Physique.* C.

THE ADHESION OF FLAT DRIVING BELTS.

By Robert Grimshaw.

Abstract of Remarks made at the Meeting of the Franklin Institute, Feb. 15, 1882.

The speaker stated that he was prepared to explain certain discrepancies and add lacking points in the theories of published experiments of Morin, Briggs & Towne, Cooper and Webber. The ordinarily accepted theories were in some cases affirmed, in some modified and in some contradicted by his tests, which up to the present time numbered over 900.

The elements governing the adhesion of flat driving belts to pulleys are pulley diameter, material and condition, and amount of crown; arc of contact, and belt material and condition, width and thickness, and tension. Each of these exerts an influence upon the adhesion; these influences being modified and in some cases neutralized, or even reversed, by the others. Of only one of them (arc of contact) it may be said that there are no apparent contradictions in its action. In his experiments Mr. Grimshaw used ten changes of pulley, ten of belts, three of arc, and about ten of tension. He employed pulleys of turned cast iron, wrought iron, and wood, and also the same pulleys covered with leather and rubber lagging; these pulleys having diameters of 18, 24, 30, and 36 inches. The belts used in testing were rubber, single and double leather oak tanned, waterproof and fulled, and wire centres; and canvass covered with composition. The arcs of contact were 90°, 180°, and 270°; and the tensions from 10 to 100 pounds per inch of belt width. The machine used for testing, and which was shown in part at the meeting, consisted of a strong wooden frame bearing a shaft $2\frac{7}{16}$ inches diameter, 5 feet long, upon which were hung the pulleys to be tested—both shaft and pulleys being held from turning.

At the meeting there were turned cast iron pulleys of 18 and 36 inches diameter, and a 36-inch "taper sleeve" wooden pulley. The belt to be tested was placed centrally upon the desired pulley, and one end weighted with a given amount per inch of width. Force is applied at the other end until the belt slowly slips. The difference between the weights on each end represents the amount of friction of the belt upon

the pulley, or the grip under the circumstances. The tension is applied by dead weights in a cage (the weight of the clamps and the cage being allowed for). The force to cause slipping is preferably applied by dead weights; but as in some cases this is considerably more than a ton, for convenience in such cases the force is applied by a lever of the second class, having its fulcrum under the centre of the shaft and its point of application of force to the belt in a vertical line tangent to the pulley at the point in the horizontal plane of the shaft. In other words, for each pulley the short arm of the lever was the same length as the radius of the pulley.

The dynamometer, one of Fairbanks' standard traction machines, is first tested by hanging dead weights upon it, at each division at which it is to be used; and in testing the belts the mean of four readings is taken; although in many cases no readings are counted until there are three consecutive ones alike.

As the result of over 900 tests and readings made, Mr. Grimshaw announced that the influence of increased pulley diameter is always to increase the drive; especially with light tensions. The influence of pulley material is so largely modified by the other conditions that no general rule can be laid down concerning it. The same is true of belt material. Increasing the belt width does not always increase the driving power, especially with thick belts, small pulleys, and light tensions. Increasing the belt thickness does not always increase the driving power, especially with small pulleys, wide belts, and light tensions. Increasing the arc of contact may be said to increase the drive in every case yet known. Increasing the tension increases the drive up to a certain point, beyond which, in many cases, no further increase of tension will cause any augmentation in the grip.

Mr. Lipman inquired as to paper belts. Mr. Grimshaw answered that these were but little used, by reason of their great stiffness and lack of elasticity; a certain degree of elasticity being a prime requisite of a belt in order to permit a difference in tension between the two sides by alternate elongation and contraction.

Mr. Fagan asked which were the most durable, rubber or leather belts. Mr. Grimshaw replied that in some situations, as for instance, in dry places, leather was the most durable; while for damp places rubber only would answer. Rubber was rapidly deteriorated by mineral oils and could not be used for quarter twist and crossed belts.

Mr. Chambers asked whether the tests as made were of any value

in determining the driving power of belts at high speeds. Mr. Grimshaw replied that the conditions of friction were substantially the same, and that conditions varied so that he could not give any reply to any question as to the relative driving power of different kinds of belts at high speeds, without all the conditions being stated.

Mr. Sandgran asked if the speaker had made any tests of canvas belts. The latter replied that he had made about 200 under varying conditions with some substance to increase the adhesion, and that its tractive powers under the conditions of his tests were exceptionally good, while it was the strongest belt that he had ever broken.

Mr. Eccles thought that the mode of testing was hardly the right one, the tendency being, by adding weights to both ends of the belt, to break it; and said that he would prefer to attach the dynamometer to the rim of the pulley. Mr. Grimshaw said that the friction between the belt and the pulley was the same as that between the pulley and the belt; that the driving power of any belt was measured by the difference between the tight and the loose sides, and that the pulley got all the difference in the tension; it could go nowhere else. As regards the danger of breaking the belts—the tension possible to put upon any belt was determined by the strength of the lacing or other fastening, and that for lacings the maximum safe strain, as laid down by Briggs & Towne, was 66⅔ pounds per inch wide; whereas single oak tanned leather belting broke at 1000 pounds per inch of width. Hence the method of testing not only registered correctly both the light and the heavy tension but the difference or grip, and did not induce artificial conditions. It had two certain practical conditions over attaching the dynamometer to the pulley rim.*

Preservation of Chestnuts.—The great consumption of chestnuts in France, both by men and by cattle, renders some contrivance for preserving them a great desideratum. M. Magne has communicated a method to the Agricultural Society, which he has found very successful. He mixes them, in November, with a dry sandy soil, and places them in a close vessel. When thus treated they can be preserved in good condition until the end of May or longer.—*Les Mondes.* C.

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* Attaching the dynamometer to the pulley rim allows only as much slip as the motion of the spring permits (about ⅛ inch in the present case); while allowing the belt to slip gives a foot or two.—R. G.

CAR JOURNAL BOXES WITH WENDELL'S LATEST IMPROVEMENT.

By C. Henry Roney, C.E.

In cars and locomotive engines the bearing carrying the car rests upon the axle so that lubrication to be effective should be on the top of the journal, the reverse of the case in stationary engines, where the journal rests upon the bearing. In the car journal boxes in ordinary use, Fig. 1, to diminish friction, cotton waste saturated with animal or mineral oils or fat is used; acting as it does by capillary attraction, it achieves the object very imperfectly; collecting dust on the surface next to the journal, or falling away from it removes the lubricating material from contact with the journal, allowing the metal surfaces to rub together and become heated; the principal cause of hot boxes, or the grit working between the surfaces wears them away much more rapidly than where the lubrication is carried on without cotton waste.

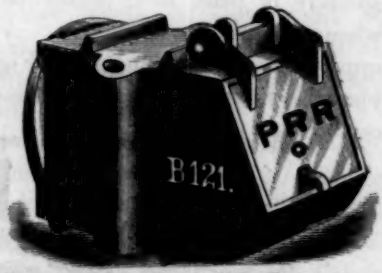


Fig. 1.—Pennsylvania R.R. Freight Box as used at present.

To overcome this deficiency Mr. Wendell has devised this improvement, consisting of a small force pump, Figs. 3, 4, 5, 6 and 8, with ball valves *C* and *D*, operated by the vertical motion of the car or truck, which pumps up oil or lubricating material from the bottom of the box through the pipe *E* to the top of the bearing, through which openings are made, carrying it directly to the top of the journal from whence it falls to the bottom of the box.

The pump (Figs. 3, 4, 6 and 8) itself is exceedingly simple in construction, consisting only of a phosphor-bronze valve seat, *H*, Figs. 4 and 6, and pump barrel, *G*, phosphor-bronze being used on account of its toughness and durability; the valves *C* and *D* are common Babbitt metal balls, while the pump plunger, *A*, is a solid piece of iron turned to fit the pump barrel, *G*, without any packing whatever, as the oil forms a sufficient packing in itself.

In the special box shown in Fig. 5 this pump, Fig. 6, is dropped into a recess in the front part of the box made to receive it, and a lid

Fig. 2.—Penna. R.R. Freight Box with Wendell's Improvement.

Fig. 3.—Inside View of Lid with Improvement.

Fig. 4.—Cross-section of Pump.

or cap is put on the top and bolted down, thus holding the pump securely in place so it cannot be loosened by the continual jarring when the train is in motion. A spiral spring is placed around the upper part of the plunger, *A*, Figs. 5 and 6, so as to return it to its place after having been pressed down by the downward plunge of the car body or truck.

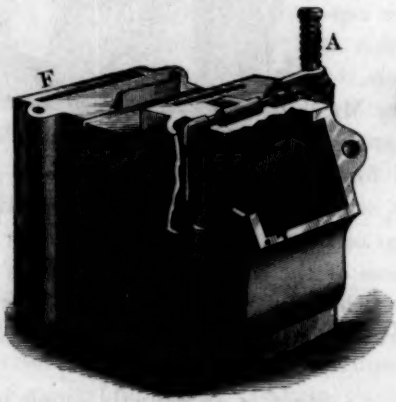


Fig. 5.—Wendell's Improvement for Steam R.R. Car Boxes.

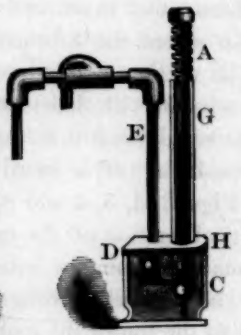


Fig. 6.—Cross-section of Pump.

Another mode of lubrication, and one that may be applied to any form of old box, Fig. 1, and consequently of much more value, is one where the pumping device, Fig. 4, is attached to the lid of the box, Figs. 2 and 3, and operated altogether by concussion, it being a weighted plunger, *I*, Fig. 4, resting on a small spiral spring of just sufficient

strength to support the plunger when the car is at rest, so that at every jar or motion of the truck the plunger will move on the spring thereby causing a small quantity of oil to be pumped up and into the bearing over the journal and thence into the bottom of the box to be again circulated. This process is constantly repeating itself while the car is in motion, consequently there is no loss of oil except such as may leak out at the shoulder of the axle or the infinitesimal portion of oil which may be oxidized or worn out.

Fig. 7.—For City Passenger Cars.

Fig. 8.—View of Pump.

By either improvement no cotton waste is used, and the oil fed to the journal is always clean and fresh, and being poured on in such quantities, any dust that may have settled on the face of either journal or bearing will be washed off and settle in the bottom of the box, where it will remain, as all the oil pumped is drawn from a sufficient distance above the bottom to allow for all settling of dirt or dust and wear.

There is a remarkably good packing around the shoulder of the journal *F*, Fig. 5, to exclude dust and dirt and prevent the waste of oil; this consists of two pieces of cork or leather cut to fit the journal, and made to break joints, so as to be contracted or expanded, by means of an iron strap and follower drawn together by small nuts, and so tighten the packing around the journal. Another plan, which renders the packing automatic, is to place one small spring under each nut, and between the nut and follower, so that the constant pressure of these springs will always keep the packing tight and prevent the escape of oil or admission of dust almost entirely, so that one supply of oil may last for a long time. This seems to be a very great improvement over the old style, where they pack the journals but loosely, and the dust getting in is sure to grind and cut the journals and bearings, and very frequently result in what every experienced traveler has cause to dislike, viz., a hot box.

With this improvement of Mr. Wendell's such a constant supply of oil is kept on the journal that a hot box is rendered next to impossible. The patentee claims that not only will this prove a great saving in the wear of bearings, as has been fully shown by many experiments of lubricating with clean oil, without waste, and from the top, but also

in power, the cars running very much lighter when the oil is fresh and clear of grit than when the cotton waste is holding all this grit and dirt up to the journal and forming a sort of emery wheel until, as is almost always the case, the bearing is worn out in one-quarter the time it would have been if the oil fed was clean.

The present cost for brasses and lubrication per eight-wheeled car per annum has been estimated (with oil at 20 cents per gallon) at $44.97. Mr. Wendell claims that by the use of his improvement a large portion of this cost may be saved.

THOMPSON'S PATENT WET PULVERIZER.

By C. Henry Roney, M.E.

Read before the Franklin Institute, January 18, 1882.

This machine in its original form has been used successfully in England for some years, but recently has been simplified and improved by S. P. M. Tasker, of Philadelphia, so that as manufactured by him it is much more effective and durable, as well as more convenient to transport and run, than the original form.

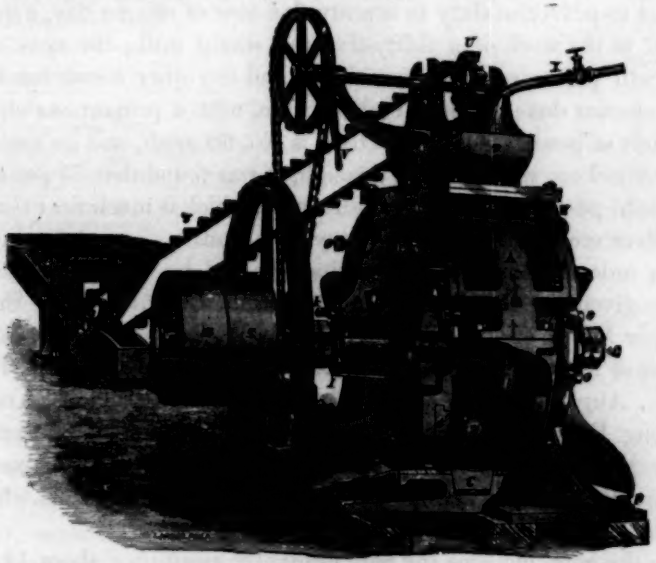
The accompanying illustration, representing a machine of a capacity of 60 tons in 24 hours, built for a Philadelphia silver mining company, will convey an accurate idea of the general character of the pulverizer, a portion of the lower portion of the machine being removed to show the working parts.

The ore fed in at *T* is crushed between the chilled charcoal iron ball *B* and the shoe ring *C* of equal hardness, the ball *B* being grasped between the disc blades *d*.

The disc blades *D D* and the disc rings *d d*, kept the proper distance apart by the spring *E*, grasping the ball *B*, are caused to revolve rapidly, and the centrifugal motion thus given the ball *B* causes it to press against the shoe ring *C* while it is being carried around by the blades, crushing any ore which may be between the ball *B* and the shoe ring *C*. At the same time that the ball is being carried around the inner circumference of the machine, it is free to revolve on an axis which is continually changing; as it is loosely grasped at two opposite points only, there is little or no scraping motion against the ring

C; and the ball always presents new surfaces against the ore, preserving its spherical form until worn down too small for further use.

The ore broken to a suitable size (about two-inch cubes) and water are fed into the hopper *T* and the pulverized ore is emitted through the screens *N* at the sides of the machine. The disc blades *D D* have diagonal slots running from the inner to the outer sides, so that any ore which is not crushed sufficiently fine at the first revolution of the ball *B* to pass through the screen *N*, is brought back under the ball and crushed sufficiently fine by succeeding revolutions.



A, Body of Machine. *a a*, Steel Wearing Plates. *B*, Ball. *C*, Shoe Ring with Wooden Cushion. *D D*, Disc Blades. *d d*, Disc Ring. *E*, Spring. *F F*, Ball Joint Clutch Journals. *G*, Shaft. *H H*, Journal Bearing Boxes. *i i i i*, Nuts for Setting Discs. *K K*, Screws for Setting Brasses. *L L*, Packing Box to Prevent Material from Getting in Journals. *m m m m*, Screws for Setting Packing Boxes. *N N*, Screens and Frames. *O O*, Screws and Clamps for Holding Screens. *P P*, Foundation Bolts. *Q*, Fly-Wheel. *R*, Fly-Wheel Fender. *S S*, Tight and Loose Driving Pulley. *T*, Hopper. *U*, Automatic Feed. *V*, Feed Clutch. *W*, Receiver for Ore. *X*, Water Supply Pipe.

Disregarding minor details, such as the driving pulleys, screens, bolts and bearings, the entire pulverizer is composed of six pieces, the bottom, the top, the disc ring and the ball. The machine is divided directly through the middle and requires no expensive foundation upon which to place it, three ordinary timbers answering all purposes and

but four bolts being required to hold it together, their removal in a few moments enabling it to be taken entirely apart.

The wearing parts of the machine, such as the ring in which the ball revolves and rolls, the discs, the ball itself are made of the best chilled charcoal iron, much harder than the best tool steel, such tools, as cold chisels, having been ground in this pulverizer to demonstrate the hardness of the metal and effectiveness of the motion.

The hardest rock may be ground with very little motive power, the largest machine—they are made of three sizes—requiring but ten horse-power to pulverize sixty to seventy-five tons of ore per day, a quantity equal to the work of a thirty-five ton stamp mill; the next smaller size will pulverize about two-thirds and the other about one-half of the amount done by the larger machine, with a proportionately small amount of power. The screen used is No. 60 mesh, and on testing the pulverized ore which passed through, it was found that 75 per cent. of it would pass through a 100 mesh screen, which is much finer than gold or silver ore is crushed by ordinary stamp mills.

In order to compare the results obtained by this pulverizer with those given for stamp mills in California, Colorado, Lake Superior Copper Mines, etc., as given by Rossiter W. Raymond, U. S. Commissioner of Mining Statistics, Prof. T. H. Eggleston, Charles M. Rolker, M.E., Aug. J. Bowie, Jr., Prof. H. S. Monroe ("Trans. Am. Inst. Mining Engineers") and E. F. Althaus, U. S. Centennial Reports, I have prepared a table, giving the maximum results obtained with stamps in different localities, together with those obtained with this machine.

In the large machine the ball, originally measuring about 11 inches in diameter and weighing 180 pounds, is used until reduced to about 9 inches in diameter and weighing 100 pounds, a loss of 80 pounds of metal, during which time about 320 tons of a hard Laurentian rock has been crushed, being about $\frac{1}{4}$ pound of iron to each ton of ore crushed; while with ordinary stamps one shoe, weighing from 300 to 320 pounds, is estimated to crush 40 tons of quartz rock before it is discarded, and loses from one to several pounds of metal to each ton of ore crushed.

The amount of water required per ton of ore for the pulverizer is also claimed to be less than one-half that required for a California stamp mill, a very important consideration, when we understand the great difficulty in obtaining water, which frequently exists in mining regions.

Location of Mill.	Stamps. Character.	Weight—lbs.	Fall—inches.	Number of drops per minute.	Size of Screen.	HP per Stamp.	Tons crushed per HP in 24 hours.	Tons crushed per Stamp in 24 hours.	Shoes, wear per ton crushed—lbs.	Water required per ton crushed—gallons.	Coarseness of Sands. 1-25 in. to 3-16 in. pr ct.	1-64 in. to 1-25 in. pr ct.	Finer than 1-64 in. pr ct.	No. 60. Per cent.	Finer than No. 100. pr ct	Space occupied—feet.	Character of Ore.
California, Eldorado County...	California Pattern..	665	10	80	No. 6	...	3·93	.....	...	5282	...	...	...	...	...	.....	Quartz.
California, Nevada County.....	"	1000	11	60	.....	...	2·00	.....	...	5282	...	...	...	...	...	.....	Quartz.
Colorado, Gilpin County.....	"	900	15	50	.....	...	3·30	.....	...	.....	...	...	...	...	...	.....	.....
Nevada, Virginia City.....	"	.....	8	100	.....	...	.....	$4\frac{1}{2}$	...	.....	...	...	...	...	...	.....	.....
Dakota, Deadwood	"	758	9	85	No. 6	...	.....	$3\frac{1}{10}$	...	.....	...	...	...	...	...	.....	Quartz.
Utah, Ontario District.....	"	800	8	92	No. 30	...	.....	$2\frac{1}{4}$	...	dry	...	...	...	...	...	.....	Very hard.
Michigan, Lake Superior, Calumet and Hecla.....	Ball Steam hammer st'mp	4500	20	90	$\frac{3}{16}$"	60	2·00	120	1	7925	28	20	52	...	...	$15\frac{1}{2} \times 12\frac{1}{2}$	Conglomerate.
Michigan, Lake Superior and Phœnix.....	Atmospheric Stamp.....	270	16	120	.....	...	.....	$6\frac{2}{3}$	...	.....	..	...	...	...	...	.....	.....
Brazil, Morro Velho.....	Cornish Pattern..	640	12	73	.....	...	1·41	.....	...	.....	...	...	...	...	...	.....	.....
Australia, Clunes, Port Phillip company.....	"	800	8	75	.....	...	3·30	.....	...	.....	...	...	...	...	...	.....	.....
Australia, Clunes, Port Phillip company.....	"	800	8	75	.....	...	2·42	.....	...	.....	..	...	..	...	...	.....	.....
Thompson's Pulverizer (S. P. M. Tasker), Size B.....	Centrifugal...	ball 180	...	230	No. 60	10	6 to $7\frac{1}{2}$	60	$\frac{1}{4}$	625	...	...	...	25	75	7 × 4	Very hard and tough Laurentian rock.
Thompson's Pulverizer (S. P. M. Tasker), Size C.....	"	120	...	300	No. 60	6	6	30	$\frac{1}{4}$	625	...	...	...	25	75	5 × 4	"
Thompson's Pulverizer (S. P. M. Tasker), Size D.....	"	70	...	400	No. 60	4	6	15	$\frac{1}{4}$	625	...	...	...	25	75	4 × 3	"

The ore receiver *W* and elevator *U* are not necessary when the rock breaker is placed on the floor above, and the broken ore fed directly into the hopper *T*, which is the most economical mode of feeding, and the plan recommended by the manufacturer.

A NEW METHOD OF DETERMINING PHOSPHORIC ACID.

By HENRY PEMBERTON, JR.

Read before the Chemical Section of the Franklin Institute, Feb. 7, 1882.

The process I am about to describe, and which I first tried in the summer of 1879 and have used since that time, consists in titrating phosphoric acid by direct precipitation, by means of a standard solution of molybdate of ammonia.

The principle is the same as that of Gay-Lussac's silver estimation, or Wildenstein's estimation of sulphuric acid by barium chloride; the standard solution is run in until further addition no longer causes a cloud, and the volume then read off.

Any one who has used ammonic molybdate for separating P_2O_5 in the usual gravimetric determination will at once see that the following obstacles will have to be overcome:

(1) The usual nitric acid solution of the molybdate is not stable, and is therefore unfitted to act as a standard solution, on account of the gradual separation of molybdic acid.

(2) The yellow precipitate does not separate completely until after the lapse of considerable time.

(3) A decided excess of the molybdate must be added to insure the complete precipitation of the P_2O_5.

(4) The precipitate has not always the same composition, being frequently mixed with free molybdic acid.

Two expedients have enabled me to overcome these difficulties: the use of an *aqueous* solution of ammonic molybdate, instead of the ordinary nitric acid solution—first advocated by John Parry (*Chem. News*, vol. xxv)—and the addition to the phosphate solution of a considerable quantity of nitrate of ammonia, in which the yellow precipitate is as good as insoluble—recommended by E. Richters (*Jour. Chem. Soc.*, 24, p. 157).

By so doing I have found that the standard solution is perfectly

stable, that the yellow precipitate falls immediately and completely, that a very small and definite excess ($\frac{1}{2}$ cc.) of the molybdate is required and that the ratio of molybdic trioxide to phosphoric anhydride is always the same.

Briefly stated, then, the process consists in adding nitrate of ammonia to the phosphate solution, using a limited quantity of nitric acid, and running in, from a burette, an aqueous solution of ammonic molybdate until, after the settling of the precipitate, the further addition of the standard solution leaves the liquid clear.

Starting out, as I did, completely in the dark, my first object was to get some general idea of the working of the proposed method. Therefore, without being exact in weights, I dissolved about 10 grammes of the molybdate in 100 cc. of water, and made a phosphate of soda solution of such strength that 50 cc. should equal 0·1000 gramme P_2O_5. 25 cc. of this phosphate solution was then treated with 2 cc. nitric acid, of 1·4 specific gravity, and with 10 grammes nitrate of ammonia. It was then heated, and the molybdate solution run in from a burette. The first drop caused an immediate precipitate. This was continued until, after settling of the yellow precipitate (which is quite rapid), further addition left the solution clear. I found, in three trials, that 25 cc. of the phosphate solution required 15·8 cc., 16·0 cc., 15·7 cc. of the molybdenum solution. This same was then repeated, but the final point was determined by filtering a little of the solution and testing it by the molybdate. 25 cc. required 15·5 cc., 15·3 cc., 15·5 cc., showing that in the first three trials, where the end of the reaction was shown by the settling of the precipitate, the point was somewhat overstepped. In all the following experiments, therefore, the end of the precipitation was determined by allowing the yellow salt to settle, filtering a little of the solution through a small filter, heating this clear filtrate, and testing it with more of the molybdate.

Nitric Acid.—Repeated above, using 5 cc. HNO_3, 1·4 sp. gr., in place of 2 cc. Required 16·0 cc., 16·0 cc., showing that a greater quantity of the molybdate is necessary in order to counteract the solvent action of the excess of nitric acid.

Ammonic Nitrate.—Proceeded as above, 2 cc. HNO_3, but used 20 grammes ammonic nitrate in place of 10 grammes, as before. Required 15·5 cc., 15·5 cc., proving that 10 grammes is sufficient when the total volume of the solution is not over 100 cc., or thereabout.

Dilution.—As above, 10 grammes NH_4NO_3, 2 cc. HNO_3, but dilu-

ted the solution so that the volume when finished equaled 130 cc., instead of from 50 to 70 cc., as above. Required 15·6 cc., showing that dilution, within moderate limits, does not affect the result.

Oxides of Iron and Alumina.—As above, but added 0·057 gramme Fe_2O_3, dissolved as nitrate, and 0·034 Al_2O_3, present as neutral tersulphate. Required 15·5 cc., proving that these sesquioxides—at least when present in above quantities—do not interfere.

The above were all preliminary trials, made merely to enable me to feel my way. Feeling encouraged by the results, I proceeded to make a more thorough examination.

10·085 grammes disodic hydric phosphate was dissolved in water and made up to 1000 cc. The amount of P_2O_5 in 50 cc. of this solution was then determined by precipitation and weighing as magnesic pyrophosphate, and also by evaporating, igniting and weighing as sodic pyrophosphate. I found in 50 cc.

By $Mg_2P_2O_7$	.	0·1010 gramme	P_2O_5
" "	.	0·1009 "	"
" $Na_4P_2O_7$	.	0·1012 "	"
Average =	.	0·10103 "	"

Showing that the salt before weighing had effloresced about 1 per cent.

93 grammes ammonic molybdate ($3(NH_4)_2O.7MoO_3.4H_2O$) were dissolved in water and made up to 1 litre, a slight cloudiness being removed by addition of a few drops of ammonic hydrate.

50 cc. of the phosphate of soda solution was then measured with a beaker, treated with 10 grammes NH_4NO_3 and with one cc. HNO_3, 1·40 sp. gr., and then warmed. Ammonic molybdate was then run in, but not a trace of a precipitate formed; but on adding another cc. of nitric acid a dense precipitate immediately formed. After adding still a third cc. of nitric acid 32·9 cc. of the molybdate were required for entire precipitation. Using, therefore, 10 grammes NH_4NO_3, 2 cc. HNO_3, 1·4 sp. gr., and titrating with the solution of 93 grammes molybdate to the litre, I found that 50 cc. P_2O_5 solution required, when the volume at the end was

115 cc.,	.	32·5 cc. 32·8 cc. 32·7 cc. } Mean = 32·70 cc.

When the volume at end was

60 cc. to 70 cc., . 32·8 cc. } Mean = 32·85 cc.
32·9 cc. }

Again, when volume = 120 cc.,

33·0 cc. } Mean = 32·90 cc.
32·8 cc. }

The means, therefore, were: 32·70 cc.
32·85 cc.
32·90 cc.

General mean = 32·82 cc. to precipitate 0·10103 grm. P_2O_5. Therefore 0·1000 gramme P_2O_5 would require 32·48 cc.

It is well known that in the usual way of precipitating this yellow salt, where a large quantity of nitric acid is present, a considerable excess of the molybdate is required. Having this in view, I tried the following experiment. Since 50 cc. of the P_2O_5 solution require, as above, 32·82 cc. molybdate, 5 cc. should require one-tenth of this, or 3·28 cc. I found, however, that 5 cc. required, in two trials, 3·7 cc. and 3·7 cc., an excess of 0·42 cc. Again, 1·5 cc. P_2O_5 solution (= 3 per cent. of 50 cc.) should require 3 per cent. of 32·82 cc. = 0·98 cc. By experiment 1·45 cc. were required, an excess of 0·47 cc. As it is not required to differentiate more finely than to the $\frac{1}{10}$ cc., it appears that 0·5 cc. excess is required, first to neutralize the slight solvent power of the HNO_3 present, and secondly to precipitate the small quantity of P_2O_5 held back in the pores of the filter paper in the final testing. Subtracting, therefore, this 0·5 cc., we find that 0·10103 gramme P_2O_5 require 32·82 cc. — 0·5 cc. = 32·32 cc. Therefore 0·1000 gramme P_2O_5 require 32·00 cc. molybdate.

Ratio of MoO_3 *to* P_2O_5.—Ammonic molybdate contains, when perfectly pure, 81·55 per cent. MoO_3. One determination of the sample I used (of German manufacture) gave me, by Chatard's method, 81·27 per cent. MoO_3. Using the theoretical figures, a litre of molybdate solution containing 93 grammes will contain 75·8415 grammes MoO_3. 32 cc., therefore, will contain 2·4269 grammes MoO_3, this representing the amount required to precipitate 0·1000 gramme P_2O_5. Therefore $MoO_3 : P_2O_5 :: 24·269 : 1$. This represents the ratio *by weight*.

Dividing by the molecular weight of each (144 and 142 respec-

tively) we get $23\frac{93}{100}$ molecules* of MoO_3 to 1 molecule P_2O_5, or practically 24 to 1.

This is precisely the figure established by Finkner, and still more recently by Dr. Gibbs in his investigation into the phosphomolybdates, just published in a recent number of the *American Chemical Journal.*

The agreement of these results, obtained in entirely different ways (those of Finkner and Gibbs by analysis, mine by synthesis) prove what I previously asserted in regard to the constancy and reliability of results by this process. In the ordinary gravimetric determination of P_2O_5, where the latter is separated by the nitric acid solution of the molybdate, the solution has to stand in the heat for several hours and in the presence of a decided excess of the reagent. It is, therefore, impossible to guarantee the absence of admixed molybdic acid, and almost every chemist analyzing the per cent. of P_2O_5 in the yellow salt obtained a different result. It is, accordingly, this fact that has prevented the universal adoption of the yellow precipitate as a basis upon which to calculate the phosphoric acid.

I have, therefore, gone somewhat minutely into this question, to prove that these sources of error do not exist in this volumetric process.

Action of Nitric Acid.—I found that 50 cc. of the P_2O_5 solution require

(With	1	cc.	HNO_3	1·4	sp. gr.—	no precipitate)
"	2	"	"	"		32·8 cc.
"	3	"	"	"		32·9 "
"	$5\frac{1}{2}$	"	"	"		33·2 "
"	$10\frac{1}{2}$	"	"	"		33·8 " —is not enough.

Action of Chlorides.—10 cc. P_2O_5 solution should require 6·46 cc. With 5 grammes NH_4Cl added required in two trials 6·60 and 6·65 cc. Again, 10 cc. P_2O_5 solution with 1·17 gramme $CaCl^2$ added require 6·55 cc. Again, 5 cc. of another P_2O_5 solution which should require 4·90 cc., when treated with 1 cc. HNO_3 and 1 cc. strong HCl requires 4·90 cc. Hence chlorides do not seem to have any appreciable effect.

Temperature.—The solution containing the phosphate has to be quite hot; a steam should play upon the surface of the liquid. One

*Even if calculated upon the basis of 81·27 per cent. MoO_3 in the molybdate (as per my analysis), the result is practically the same, viz.: $23\frac{44}{100}$ MoO_3 to P_2O_5.

determination showed 136°Fahr.; this should certainly be regarded as the minimum. A solution of known strength, to which about 90 per cent. of the molybdate required had been added, and which had been kept only slightly warm, was filtered, and the filtrate heated. A decided yellow precipitate at once formed. From 140° to 160°Fahr., or even somewhat higher, appears to be about the correct temperature.

Action of Silicic Acid.—Halloysite was decomposed with sulphuric acid, the silica filtered, washed, and boiled repeatedly with HCl. Again washed, dried and ignited. 0·1725 gramme of this ignited silica was fused with Na_2CO_3, dissolved in water, neutralized with HNO_3, treated with 10 cc., P_2O_5 solution, and then titrated. It should have required 6·45 cc. molybdate, but did require 7·5 cc., and even when 8·7 cc. had been added, gave with more molybdate, at first a yellow color, and after standing, a faint cloud. Silicic acid therefore interferes.

Action of Organic Matter.—The material used for this purpose is what is known in the trade as "azotine" or "ammonite." Refuse from slaughter-houses, dead animals, etc., are subjected to a treatment with hot benzine, by which the fat is extracted. The residue consists of a certain amount of bone with every variety of organic matter except the fat, and as it comes into the market in a fine dry powder, is well adapted to examination, weighing, etc. It was with particular reference to the analysis of fertilizers that I selected this substance as a typical form of organic matter likely to be found in these.

Before examining this, there are a few points to be noticed. First, Mulder has shown (*Chem. Gazette*, vii., p. 62) that higher results are obtained by treating organic compounds containing phosphorus with HNO_3 than are obtained by dissolving in HCl. He finds that the excess of P, oxidized by HNO_3 over the quantity dissolved by HCl, and calculated into phosphoric acid, to be, with albumen, 0·99 per cent., albumen in blood, 0·76 per cent., fibrin, 0·76. It has not been established that phosphorus, in organic combination, is of any value as plant-food. In fact, from the nature of the case, it never will be decided.

Secondly. Although shown by Kastner to be the case over half a century ago, it is, in all probability, not generally known that the phosphoric acid in calcined bones exists not as ortho-phosphoric acid, but chiefly as pyro- or meta-phosphoric acid; and this, too, in spite of the fact that three atoms of base are present.

Thirdly. In igniting the azotine, to burn off the organic matter,

the small quantity of dirt, sand, etc., always present, yields a certain amount of soluble silicic acid, on subsequent treatment with acid, and this will interfere, unless the solution is evaporated to dryness.

The following are the analyses of several brands of this azotine: By "volumetric" is meant that the determination is made by titration with ammonic molybdate. By MoO_3 and MgO that the usual gravimetric method was used.

Volumetric. Ignited azotine, evaporated to dryness, 14·19 per cent. P_2O_5.
" " " not " " " 14·50 " "
" " " not " (2d analysis) 14·64 " "

showing the action of silica.

Volumetric. Raw azotine (not ignited) dissolved in HNO_3, evaporated twice, . . . 15·05 per cent.

showing the action of oxidizing agents.

Another sample gave:

MoO_3 and MgO., raw azotine, HCl solution, 2·87 per cent. P_2O_5
Volumetric " " " " 2·73 " "
" " (repeated) . . 2·67 " "
" Ignited, evaporated to dryness, 2·90 " "
" Same repeated, . . . 3·06 " "
" Ignited (not evap., action of SiO_2), 3·20 " "

Another sample:

MoO_3 + MgO raw azotine, . . 4·45 per cent. P_2O_5
Volumetric " . . 4·57 "
" " $HNO_3 + KClO_3$. 5·21 "
" same repeated, . . 5·60 "
" Ignited but not evaporated, . 4·84 "
" same repeated, . . 4·91 "

I now made a mixture of acid phosphate of lime from South Carolina phosphate rock and sulphuric acid, containing (about)

9 per cent. soluble P_2O_5
$3\frac{1}{2}$ " reverted "
$2\frac{1}{2}$ " insoluble "
15 per cent. total "

This was mixed so as to contain in 100 parts of the above acid

Phosphate, . . . 79 parts
Azotine, ... 16 "
Potassium chloride, . . 5 "
100 "

and this mixture, after being finely ground and averaged, was analyzed, as follows:

By $MoO_3 + MgO$ (not ignited, . .	13·32	per cent. P_2O_5
Volumetric, ignited, evaporated to dryness,	13·25	" "
(Showing no loss from formation of pyrophosphate).		
Volumetric, not ignited, HCl solution evap'd,	13·11	" "
	13·07	" "
	13·24	" "
Volumetric " " *not* evaporated,	14·03	" "

Again, the above mixture was leached, filtrate not measured, but 25 cc. (= about 0·8 gramme) taken for each trial.

By $MoO_3 + MgO$ (evaporated to dryness with HCl)	70·7	mgr. P_2O_5
Volumetric, " " "	69·3	" "
" not evaporated, . .	71·1	" "

From the above it appears that by dissolving in HNO_3 and evaporating to dryness, the results are above the truth; by dissolving in HCl, the result may be 0·1 per cent. to 0·2 per cent. low; by igniting and not evaporating, the silica will interfere; but that by igniting and evaporating to dryness the results are correct, or vary only within the limits of instrumental errors.

I have observed no difficulty in working with pyrophosphates, provided that the ignition be carried on at not too high a temperature, and the evaporation with nitric acid be repeated.

Citric, tartaric and oxalic acids interfere and must not be present. When the oxalic acid is oxidized by permanganate, the yellow precipitate falls immediately.

The following is a condensed description of the modus operandi in performing the analysis.

89·5430 grammes ordinary ammonic molybdate are put into a litre flask, water added and the whole shaken until the salt dissolves. If a cloudiness is left in the liquid, a little ammonic hydrate is added. A small excess of this is not objectionable. The flask is then filled to the mark.

The above weight of the molybdate is calculated so as to give MoO_3 to P_2O_5 exactly as 24:1. Each cc. precipitates 3 milligrammes P_2O_5. It differs from the figure obtained empirically by an amount equal to only 0·0003 gramme P_2O_5 in a determination of 0·1000 gramme P_2O_5.

The phosphate to be examined is then taken in quantity containing not over 0·1000 gramme P_2O_5 or 0·1500 gramme at the utmost. If

silica is present the solution is evaporated to dryness. In presence of organic matter ignite gently and evaporate to dryness twice with HNO_3. There is no advantage in filtering off the SiO_2. The solution is transferred to a beaker of 100 to 125 cc., using as little water as possible to prevent unnecessary dilution, and is just neutralized with NH_4HO, *i. e.*, until a slight precipitate is formed.

If much iron is present the ammonia is added until the yellow color *begins* to change to a darker shade. 2 cc. of nitric acid are added. Care must be taken that the sp. gr. of the acid is not less than 1·400, otherwise more must be added. 10 grammes of granular nitrate of ammonia are now added. After a little experience the quantity can be judged with sufficient accuracy by the eye without the trouble of weighing. The solution is now heated to 140°F. or over and the molybdate solution run in (most conveniently from a Gay-Lussac burette), meanwhile stirring the liquid. The beaker is now left undisturbed for about a minute on the water-bath or hot plate and the precipitate settles, leaving the supernatant liquid not clear but containing widely disseminated particles, in which the yellow cloud can easily be seen on the further addition of the molybdate. This addition is continued as long as the precipitate is thick and of a deep color. But as soon as it becomes rather faint and thin, a little of the solution, about 2 to 3 cc., after settling of the precipitate, is filtered through a small filter (not over 5 cm. in diameter) into a very small beaker, and this is heated on a hot plate and 4 or 5 drops of the molybdate added. If a precipitate is produced the whole is poured back into the large beaker and a further addition of the molybdate (1, 2 or 3 cc.) added, according to the quantity of the precipitate in the small beaker. After stirring and settling, another small quantity is filtered through the small filter and again tested. If the mark has been overstepped and too much molybdate added a measured quantity of P_2O_5 solution of known strength is added, and the corresponding amount of P_2O_5 deducted. In filtering through the small filter the liquid held sometimes in the neck of the funnel must be allowed to run out.

I generally check my results by adding a cc. of standard P_2O_5 solution, and then again testing. This can be repeated as often as desired. The portion that *last* produces a cloud, is the final point. From this is substracted 0·5 cc. (for neutralizing the solvent action of the HNO_3, as above explained), and the remainder multiplied by 3 gives the weight of P_2O_5 in milligrammes.

One decigramme of P_2O_5 gives about 2¾ grammes of the yellow precipitate, and the accuracy of the process is largely due to this smallness of the percentage of the P_2O_5.

The ammonic molybdate is now prepared in a state of great purity. Several samples that I have bought did not vary in strength to any appreciable extent. It may, possibly, contain a trace of phosphoric acid which, however, does not affect the result, since it will have the same weakening action in the standardizing tests that it has in the actual analysis.

I have used this process entirely in determining phosphoric acid in materials containing it in quantity, *e. g.*, apatite phosphate rock, fertilizers, etc.

It is *not* adapted to the direct determination of minute quantities of phosphorus in iron or iron ores. At least 5 grammes of the ore must be taken, and in the concentrated solution formed by this quantity of the iron salt and the nitrate of ammonia, the precipitate settles slowly on account of the density, and is seen with difficulty because of the depth of color. Moreover, I have observed that a solution of ferric nitrate shows a somewhat peculiar behavior on addition of ammonic molybdate; molybdic acid at once separates in a curdy precipitate which redissolves on stirring. This reaction does not take place when iron is absent. Ferric nitrate, moreover, has the effect of retarding the precipitation somewhat, and it, therefore, is more difficult to see how the precipitation is proceeding, when Fe_2O_3 is present in quantities exceeding a decigramme or so. These properties are peculiar to iron oxide only, and not to alumina.

In working with unknown quantities the titration requires about an hour for its performance. Of all the forms of volumetric analysis, that one, in which the final point is determined by the cessation of the precipitation is the least desirable. And were it not that the ordinary method requires a day rather than an hour (including at least two precipitations of the magnesia salt), the process of direct precipitation above described would hardly be able to hold its own in comparison.

I have obtained very sharp and accurate results by determining the amount of the yellow precipitate, (formed as above, after thorough washing) by means of a standard solution of caustic alkali, using litmus as an indicator; a description of which I hope to present in a future paper.

I mention it here simply to place the fact on record.

THE ANALYSIS OF IRON ORES CONTAINING BOTH PHOSPHORIC AND TITANIC ACIDS.

By Thomas M. Drown, M.D., and P. W. Shimer, M.E., Easton, Pa.

Read at the Meeting of the American Institute of Mining Engineers, Oct., 1881.

The precipitation of phosphoric with titanic acid by boiling an iron solution which had been reduced to the ferrous condition by sulphuretted hydrogen or sulphurous acid was first noticed by E. H. Bogardus in 1874.* Since that time, as far as we are aware, not much has been published on the relation of these two acids to each other, and to silicic acid in the ordinary course of analysis of iron ores. The following investigation may perhaps aid in clearing up some of the obscure points in the analysis of titaniferous ores.

The Determination of Phosphorus.

From two to five grammes of the finely powdered ore are weighed into a beaker and treated with abont 50 cc. of hydrochloric acid (sp. gr. 1·12), evaporated to dryness, and heated in an air-bath for an hour to 110° to 120°C. To the dry mass are added 50 cc. of hydrochloric acid (1·12), and the solution filtered off from the insoluble residue. On washing this residue with water the filtrate often runs through turbid. This can be avoided by washing with dilute nitric acid, or, better, with an acid solution of ammonium nitrate. The filtrate contains the greater part of the phosphoric acid, but the residue may contain a notable amount.

Treatment of the Residue.—Fuse the residue with sodium carbonate and extract with water. Sodium phosphate and silicate go into solution and sodium titanate remains insoluble. Filter, acidify the filtrate with nitric acid, evaporate to dryness, moisten with nitric acid, and dissolve in water. Filter from the silica, concentrate the filtrate, neutralize nearly with ammonia, and precipitate with ammonium molybdate. This is the best method of separating the phosphorus from the insoluble residue. The bulk of the phosphorus may, however, be extracted from the moist residue by washing with ammonia.

Treatment of the Filtrate.—Evaporate to a small bulk, and add

* *American Journal of Science*, III, 8, p. 334.

enough nitric acid to drive off all the hydrochloric acid on evaporation. If the concentrated solution is clear, add ammonia until a slight permanent precipitate is formed; redissolve this in a few drops of nitric acid, and add ammonium molybdate solution.

In the ores of which we are speaking, a precipitate generally separates on evaporating to a small bulk. The addition of more nitric acid with continued heat often redissolves this; in this case, the evaporation must not be carried too far, or the substance will again precipitate. This precipitate contains phosphoric acid and titanic acid. If it is impossible to get it into solution in nitric acid, it must be filtered off and washed with ammonium nitrate solution. It is then ignited, fused with sodium carbonate, extracted with water, and the filtrate, after acidifying with nitric acid, precipitated with molybdate solution.

After the addition of the ammonium molybdate to the main solution, as mentioned above, it is heated rather hot, say from 50° to 70°C., for half an hour, with frequent vigorous stirring. The precipitate is usually allowed to stand over night, but if filtered within two hours, there will be no appreciable amount of phosphorus unprecipitated. The yellow precipitate is filtered off and washed well with a mixture of 325 cc. of nitric acid (sp. gr. 1·2), 100 cc. of ammonium hydrate (sp. gr. 0·96), and 100 cc. of water. It is then dissolved upon the filter in dilute ammonia. The solution will probably run through turbid, and a gelatinous residue will remain in the filter. The solution is heated for some time and filtered, and this residue, which contains both phosphoric and titanic acid, is treated, together with the gelatinous residue insoluble in ammonia, with nitric acid, and the resulting solution precipitated with ammonium molybdate. By heating and stirring, the phosphoric acid can be completely precipitated in an hour, so that it will not retard the analysis materially. The solution of this yellow precipitate in ammonia is to be added to the main ammoniacal solution, and magnesia mixture added with the usual precautions. By active stirring after the addition of magnesia mixture the complete precipitation of the phosphoric acid may be effected in an hour or two.* In the analysis of an ore containing 4·74 per cent. of phosphoric acid (mostly as apatite) and 0·65 per cent. of titanic acid, the phosphoric acid was found (in duplicate analyses) as follows:

* The action of stirring or other agitation in hastening precipitation, although well known, is not, I think, as often made use of in analysis as it might be.

	I.	II.
Phosphoric acid in the hydrochloric acid solution, .	4·370	4·330
Phosphoric acid in the residue insoluble in hydrochloric acid, ...	0·280	0·390
Phosphoric acid in the precipitate which separated from the solution of the yellow precipitate in ammonium hydrate, . .	0·016	0·027
Total, ...	4·666	4·747

Determination of the Titanic Acid.

One to two grammes of the finely powdered ore are weighed into a large platinum crucible. Potassium bisulphate* to the amount of 12 to 15 times the weight of the ore is next weighed out in another vessel. Mix the ore in the bottom of the crucible with about one-quarter of the bisulphate, and fuse until the excess of sulphuric acid is nearly all driven off. During the progress of the fusion, the lid must be lifted a very little at short intervals, in order to watch the state of the fusion. It should not be allowed to rise above two-thirds the height of the crucible. Add now another quarter of the bisulphate, and heat again as before, until nearly all the excess of sulphuric acid is driven off. Then add the remaining half of the bisulphate, and heat until the whole mass is in quiet fusion. Too much sulphuric acid should not be driven off at this stage, or the subsequent solution in water will be retarded. The fused mass may be poured out into a large platinum dish, or it may be removed from the crucible in one lump by inserting a stout piece of platinum wire while still soft, and allowing the mass to solidify about it. A gentle heat on the outside of the crucible will quickly loosen the mass, which may now be lifted out easily. The former method is preferable, because of the thinness of the mass and its readier solubility.

When the mass has become cold, it is dissolved in plenty of cold

* In order to make a successful determination of titanic acid, it is necessary to have good potassium bisulphate. This can seldom be bought in a condition fit for use. It usually contains water; sometimes an excess of sulphuric acid; it also usually contains an insoluble siliceous residue. To prepare it for use, it is dissolved in water and filtered, the solution evaporated to dryness, and fused until all the water is driven off and the mass is in quiet fusion. It is sometimes necessary to drive off some sulphuric acid. It is then powdered for use. Bisulphate thus prepared will not mount readily in the crucible, and a quiet fusion at a red heat can be obtained.

water. This usually requires at least twelve hours. When it is evident that all has dissolved but silicates,* filter into a large beaker. This insoluble residue should, after ignition, be again fused with bisulphate and tested as below for titanic acid. To the main solution we add sodium carbonate solution until a slight permanent precipitate is obtained, then 3 to 4 cc. of sulphuric acid of 1·23 sp. gr. This redissolves the slight precipitate and makes the solution sufficiently acid.

Add now sulphurous acid in excess, and dilute largely with water (1 to 1·5 litre); cover with a watch-glass, and boil about two hours, adding sulphurous acid solution and water as the evaporation goes on.

The titanic acid is precipitated, and with it phosphoric acid and oxide of iron. Filter hot (best done by means of a siphon), and wash with hot water. This precipitate of titanic acid and phosphoric acid is not finely granular like that of pure titanic acid, but is flocculent, and shows no tendency to run through even a very porous filter. It is dried, ignited, and weighed. In spite of the fact that it contains a very notable amount of iron, it is usually white after ignition. It is fused with sodium carbonate and extracted with water. Sodium titanate and oxide of iron remain insoluble, while sodium phosphate goes into solution. The residue is dissolved in sulphuric acid (sp. gr. 1·23), filtered, neutralized with sodium carbonate, 2 to 3 cc. of sulphuric acid added, and then sulphurous acid as above. The titanic acid precipitated from this solution is free from phosphoric acid and iron.

If, instead of fusing the first precipitate of titanic acid with sodium carbonate, it is re-fused with potassium bisulphate, there will remain on treatment with cold water an insoluble residue containing titanic acid and phosphoric acid.

The following analytical resulte will illustrats the foregoing description:

	I.	II.
First precipitate of titanic acid containing phosphoric acid and iron (in duplicate), per cent., .	3·18	2 40

No. 1 was fused with sodium carbonate and treated with water as above. It consisted of:

* In ores containing lime, calcium sulphate is often found in this insoluble residue.

Titanic acid,	0·65
Phosphoric acid,	1·60
Sesquioxide of iron,	·84
Loss,	·09
	3·18

No. 2 was fused with potassium bisulphate, and gave:

Residue insoluble in cold water,	1·83
Precipitate by boiling the solution,	·34
Sesquioxide of iron, by difference,	·23
	2·40

The titanic acid precipitated by boiling (·34) contained both phosphoric acid and iron.

The residue insoluble in cold water (1·83) was fused with sodium carbonate as described above; it gave:

Phosphoric acid,	·96
Titanic acid,	·42
Sesquioxide of iron, by difference,	·45
	1·83

The precipitate by boiling (·34), similarly treated, gave:

Phosphoric acid,	·05
Titanic acid,	·12
Sesquioxide of iron, by difference,	·17
	·34

The complete analysis of the original precipitate (2·40) thus shows:

Titanic acid,	·54
Phosphoric acid,	1·01
Sesquioxide of iron, by difference,	·85
	2·40

The titanic acid is here doubtless ·10 per cent. too low, owing to the many fusions and precipitations to which it was subjected.

Determination of Iron.

If the ore contains less than one per cent. of titanic acid, no appreciable error will result from neglecting it. If it contains more than this, the iron must be determined in the filtrate from the titanic acid.

The first precipitation of titanic acid contains iron. This is separated by the sodium carbonate fusion, and may be added to the main solution after separation of the titanic acid. The iron is then determined by reduction with zinc and titration with permanganate.

Determination of Silica and Alumina.

When an iron ore containing phosphoric and titanic acids is treated for silica by the usual method (fusion with sodium carbonate, solution in dilute hydrochloric acid, evaporation to dryness, and separation of silica at 110°C., solution in hydrochloric acid and water, and filtration from the insoluble residue), the siliceous residue consists of silica, titanic acid, phosphoric acid, and iron. In the case of an ore containing 3·50 per cent. of silica, this residue (which, in spite of the iron in it, is white after ignition) amounted to 6·11 per cent. The presence of phosphoric acid and iron with the silica of course renders worthless the estimation of alumina by difference.

Before speaking of the determination of the silica, we will consider how we may get the phosphoric acid and iron into the main solution where they belong. The insoluble residue (containing silica, titanic acid, phosphoric acid, and iron) is fused with sodium carbonate, and extracted with water. Sodium phosphate and silicate dissolve, and sodium titanate and ferric oxide remain behind. Acidify the filtrate with hydrochloric acid, and evaporate to dryness; take up with hydrochloric acid and water, and filter off the silica; add the filtrate to the solution to be precipitated by sodium acetate. Dissolve the residue insoluble in water (containing the sodium titanate and ferric oxide) in sulphuric acid, and separate the titanic acid from the iron by boiling, as usual. Filter from the titanic acid, and add bromine-water to the filtrate, in order to oxidize the iron, boil, and precipitate the iron with ammonia. Filter and weigh it with the precipitate of iron, alumina, and phosphoric acid, separated as basic acetate.

Some titanic acid may go into the filtrate, which is to be precipitated by sodium acetate. In this case it will contaminate the precipitate of iron, alumina, and phosphoric acid. It is therefore necessary, after this precipitate has been weighed, to grind it in an agate mortar, and weigh out accurately as much of it as possible, fuse with potassium bisulphate, and determine the titanic acid in it by boiling, etc. The titanic acid thus found is to be deducted from the weight of the original

precipitate. There will not in all cases be titanic acid in this precipitate, but it is not safe to omit testing for it.

The silica may also be determined by fusing the residue from the second bisulphate fusion for titanic acid with sodium carbonate, and separating the silica as usual. Or it may be determined by fusing 1 to 1·5 grams of the ore with sodium carbonate, dissolving in hydrochloric acid, and adding an excess (50 cc.) of sulphuric acid (1·23), and evaporating until all the hydrochloric acid is driven off. This renders the silica insoluble. By now dissolving the ferric sulphate in a large excess of hydrochloric acid by aid of heat, everything goes into solution but the silica. When this point is reached, it is known by the absence of everything but transparent gelatinous silica floating in flocks in the clear solution. Calcium sulphate may contaminate the silica, if the ore contains much lime; but it does not look like gelatinous silica, and dissolves on dilution with water.

The following determinations illustrate the foregoing description:

	I.	II.
Insoluble in hydrochloric acid,	6·11 per cent.	5·38 per cent.

Fused with sodium carbonate and extracted with water, solution contained:

I.		II.	
Silica,	3·31	Silica,	3·63
Phosphoric acid,	1·03	Phosphoric acid,	·71

Residue contained:

I.		II.	
Titanic acid,	·65	Titanic acid.	·65
Sesquioxide of iron,	1·53	Sesquioxide of iron,	·58

Totals.

	I.	II.
Silica,	3·31	3·63
Phosphoric acid,	1·03	·71
Titanic acid,	·65	·65
Sesquioxide of iron,	1·33	·58
	6·32	5·57

	I.	II.	III.
Silica made insoluble by sulphuric acid,	3·40	3·48	3·54
Silica from residue insoluble in bisulphate,	3·70	3·74	.....
Residue insoluble in bisulphate,	4·91	5·03	.....

Mr. JULIAN KENNEDY, of Pittsburg, said that the slow solution of the potassium bisulphate, after fusion, could be avoided by the following procedure. When the fusion is complete enough concentrated sulphuric acid is added so that the resulting mass shall be pasty on cooling. This mass may then be dissolved promptly by aid of heat, the excess of sulphuric acid preventing the separation of titanic acid. The excess of acid is subsequently neutralized when the titanic acid is to be precipitated by boiling.

THE CONDITION OF SULPHUR IN COAL, AND ITS RELATIONS TO COKING.

By THOMAS M. DROWN, Easton, Pa.

Read at the Meeting of the American Institute of Mining Engineers, Feb., 1881.

At the meeting of the Institute in New York, in February, 1880,* I described a process of determining sulphur in metallic sulphides, with especial reference to the determination of pyrites in coal. The process, as then described, is as follows: A solution of sodium hydrate, of 1·25 specific gravity, is saturated with bromine. If an excess of bromine is used it must be neutralized by the addition of a little more sodium hydrate. The pulverized mineral or coal is moistened with 25 cc. of this solution and heated, then hydrochloric acid is added cautiously to just acid reaction. This operation is repeated with another 25 cc. of the alkaline solution, and again rendered acid. The mixture should be kept hot. The contents of the beaker or dish are then evaporated to dryness, to separate silica, and taken up by dilute hydrochloric acid. The sulphuric acid is precipitated, with the usual precautions, by barium chloride. In the paper referred to determinations by this process of sulphur in coal were given, which, although agreeing closely with one another, yet fell far short of the total sulphur in the coal, and the inference was that the sulphur not oxidized by the treatment with the bromine solution was an organic constituent of the coal, and could only be determined by a process which would oxidize the coal completely.

* Transactions of the American Institute of Mining Engineers, vol. viii, p. 569.

I am now able to give further results of the application of this process to the analysis of coal and coke. The object in view in this investigation was to determine, if possible, the effect of coking on the amount and condition of sulphur in the coal. Although the results in this regard are not as decisive as could be wished, yet many interesting facts have been noticed in the course of the work.

The coals used were from Pennsylvania and Virginia, and will be simply designated by letters. Two series of experiments were made. In the first the coke was made in the laboratory, in platinum crucibles; and in the second, "industrial coke," made in beehive ovens, was used.

In the first series the total sulphur was determined, by way of control, by fusion with alkaline carbonates and nitre; and in the second by Eschka's method of heating the coal with calcined magnesia and sodium carbonate.

First Series.

Coal A.

Proximate Analysis.		Analysis of Ash.	
Moisture,	0·75	Silica,	47·74
Volatile matters,	15·35	Alumina and oxide of iron,	34·17
Fixed carbon,	66·10	Lime,	7·61
Ash,	17·80	Magnesia,	0·98
		Sulphuric acid,	5·30
	100·00		95·80

The small quantity of ash used for this analysis is doubtless the cause of the imperfect result.

Sulphur Determinations in Coal *A*.

I. By Bromine Mixture.	II. In residue from I by combustion in oxygen, and absorption by solution of potassium permanganate.	III. In Ash from II by fusion with sodium carbonate.	IV. Total, sum of I, II and III.	V. By direct combustion of coal in oxygen, and absorption by solution of potassium permanganate.	VI. In Ash from V by fusion with sodium carbonate.	VII. Total, sum of V and VI.	VIII. Total by fusion with sodium carbonate and nitrate.
1·660	0·640	0·040	*2·340*	1·983	0·203	*2·186*	*1·940*
1·640	0·520	0·043	*2·203*	1·768	0·329	*2·097*	*1·980*
1·670	0·563	0·026	*2·259*	1·942	0·212	*2·154*	

Sulphur Determinations in Coke *A*.

1·073	0·747	0·065	*1·885*	1·287	0·477	*1·764*
1·180	0·666	0·062	*1·908*	1·290	0·494	*1·784*
1·180	0·627	0·045	*1·852*			

Coal B.

Proximate Analysis.		Analysis of Ash.	
Moisture, . .	3·48	Silica, . .	28·89
Volatile matters, .	25·25	Alumina and oxide of iron,	65·92
Fixed carbon, .	66·63	Lime, . .	2·49
Ash, . .	4·34	Magnesia, . .	0·57
		Sulphuric acid, .	2·02
	100·00		99·89

Sulphur Determinations in Coal *B*.

I. By Bromine Mixture.	II. In residue from I by combustion in oxygen, and absorption by solution of potassium permanganate.	III. In Ash from II by fusion with sodium carbonate.	IV. Total, sum of I, II and III.	V. By direct combustion of coal in oxygen, and absorption by solution of potassium permanganate.	VI. In Ash from V by fusion with sodium carbonate.	VII. Total, sum of V and VI.	VIII. Total of fusion with sodium carbonate and nitrate.
0·041	0·450	0·031	*0·522*	0·431	0·058	*0·489*	*0·474*
0·035	0·464	0·037	*0·536*	0·461	0·035	*0·496*	*0·473*
				0·454	0·053	*0·507*	

Sulphur Determinations in Coke *B*.

0·034	0·406	0·060	*0·500*	0·429	0·087	*0·516*	*0·495*
0·056	0·400	0·063	*0·519*	0·441	0·080	*0·521*	*0·536*

Coal C.

Proximate Analysis.		Analysis of Ash.	
Moisture, . .	1·16	Silica, . .	60·94
Volatile matters, .	33·08	Alumina and oxide of iron,	32·86
Fixed carbon, .	61·81	Lime, . .	1·75
Ash, . .	3·95	Magnesia, . .	0·10
		Sulphuric acid, .	2·28
	100·00		97·93

SULPHUR DETERMINATIONS IN COAL *C.*

I. By Bromine Mixture.	II. In residue from I by combustion in oxygen, and absorption by solution of potassium permanganate.	III. In Ash from II by fusion with sodium carbonate.	IV. Total, sum of I, II and III.	V. By direct combustion of coal in oxygen, and absorption by solution of potassium permanganate.	VI. In Ash from V by fusion with sodium carbonate.	VII. Total, sum of V and VI.	VIII. Total by fusion with sodium carbonate and nitrate.
0·127	0·647	0·028	*0·802*	0·693	0·036	*0·729*	*0·766*
0·139	0·631	0·022	*0·792*	0·701	0·030	*0·731*	*0·712*
				0·762	0·035	*0·797*	

SULPHUR DETERMINATIONS IN COKE *C.*

0·041	0·547	0·026	*0·614*	0·583	0·033	*0·616*	*0·640*
0·018	0·582	0·028	*0·628*	0·605	0·034	*0·639*	*0·650*

It has been recently stated by Mixter* that bromine water, or a solution of bromine in hydrochloric acid, fails to oxidize all the sulphur dioxide produced by the combustion of coal, and that the vapors should be carried into a large bottle containing bromine vapors before they are allowed to escape. I have found, also, that a final large bromine bottle collects a very small amount of sulphuric acid after the vapors have passed through a solution of potassium permanganate. A coal containing 0·721 per cent. of sulphur gave 0·009 per cent. in the large bromine bottle, and another coal containing 0·605 per cent. gave 0·024 per cent. In the following experiments the large bromine bottle was used, and the sulphur given as absorbed by permanganate solution includes the small amount found in the bromine bottle. As stated in a previous paper, I much prefer potassium permanganate to bromine for the oxidation of sulphur dioxide or sulphuretted hydrogen.

In the combustion of bituminous coals in oxygen explosions frequently occur. These may be avoided by simply diluting the oxygen with atmospheric air to the extent of equal volumes. The coal or coke can be best ignited in the tube in the following manner. The platinum boat containing the coal is placed just within the tube, which

* *American Chemical Journal*, ii, 396.

is then filled with oxygen. The cork is then removed, and a glowing splinter of charcoal placed in the end of the boat, which is quickly pushed into the middle of the tube. The flow of oxygen is at once resumed, and the coal continues to glow until it is all consumed. The gas in the combustion furnace is kept turned low until the coal is nearly consumed, when it is turned on to a good red heat.

In the foregoing experiments the coke was made in platinum crucibles over a Bunsen burner. To test the effect of coking on an industrial scale, I had samples taken of the coal, which was put into an oven, and of the coke which came out. This was not done under my supervision, and consequently some uncertainty exists as to the thoroughness of the sampling. The following are the results obtained on three samples of coal and the corresponding coke made in ovens.

The total sulphur was directly determined in these coals and cokes by Eschka's method of heating with calcined magnesia and sodium carbonate, and oxidizing the solution in water by bromine. This is much to be preferred, in regard to simplicity and accuracy, to fusion with alkaline carbonates and nitre.

Second Series.

Coal E.

Proximate Analysis.

Volatile matters (including moisture),	24·25
Fixed carbon,	70·51
Ash,	5·24
	100·00
Ash in coke,	5·41

The ash determinations in this coal and coke indicate imperfect sampling.

Sulphur Determinations in Coal *E.*

I. By Bromine Mixture.	II. In residue from I by combustion in oxygen.	III. In Ash from II.	IV. Total.	V. Direct combustion in oxygen.	VI. In Ash from V.	VII. Total.	VIII. Total by Eschka's method.	IX. Iron.
0·155	0·488	0·020	*0·663*	0·721	0·044	*0·765*	*0·733*	0·32
0·156	0·478	0·017	*0·651*	0·679	0·032	*0·711*		

SULPHUR DETERMINATIONS IN COKE *E.*

0·119	0·532	0·012	*0·663*	0·637	0·021	*0·658*	*0·665*
0·125	0·533	0·013	*0·671*	0·669	0·017	*0·686*	

Coal F.

Proximate Analysis.

Volatile matters (including moisture),	29·75
Fixed carbon,	62·37
Ash,	7·88
	100·00
Ash in coke,	9·80

SULPHUR DETERMINATIONS IN COAL *F.*

I. By Bromine Mixture.	II. In residue from I by combustion in oxygen.	III. In Ash from II.	IV. Total.	V. Direct combustion in oxygen.	VI. In Ash.	VII. Total.	VIII. Total by Eschka's method.	IX. Iron.
0·349	0·560	0·014	*0·923*	0·923	0·045	*0·968*	*0·949*	0·666
0·354	0·546	0·012	*0·912*	0·905	0·043	*0·948*		

SULPHUR DETERMINATIONS IN COKE *F.*

0·296	0·619	0·012	*0·927*	0·907	0·017	*0·924*	*0·917*
0·299	0·607	0·008	*0·914*	0·913	0·024	*0·937*	

Coal G.

Proximate Analysis.

Volatile matters (including moisture),	38·01
Fixed carbon,	56·27
Ash,	5·72
	100·00
Ash in coke,	8·76

SULPHUR DETERMINATIONS IN COAL *G*.

I. By Bromine Mixture.	II. In residue from I by combustion in oxygen.	III. In Ash from II.	IV. Total.	V. Direct combustion in oxygen.	VI. In Ash from V.	VII. Total.	VIII. Total by Eschka's method.	IX. Iron.
0·129	0·588	0·018	*0·735*	0·749	0·042	*0·791*	*0·759*	0·290
				0·727	0·045	*0·772*		

SULPHUR DETERMINATIONS IN COKE *G*.

0·085	0·516	0·025	*0·626*	0·581	0·050	*0·631*	*0·597*
				0·605	0·016	*0·621*	*0·590*

I add an analysis of anthracite, illustrating this method of treatment.

Anthracite.

Analysis of Ash. (5·11 per cent.)

Silica,	50·06
Alumina and iron,	44·22
Lime,	1·39
Magnesia,	0·21
Sulphuric acid,	2·05
	97·93

SULPHUR DETERMINATIONS IN ANTHRACITE.

I. By Bromine Mixture.	II. In residue from I by combustion in oxygen.	III. In Ash from II.	IV. Total.	V. Direct combustion in oxygen.	VI. In Ash from V.	VII. Total.	VIII. Total by fusion with sodium carbonate and nitrate.
0·08	0·485	0·024	*0·589*	0·512	0·042	*0·554*	*0·589*
				0·534	0·040	*0·574*	

No calcium sulphate was found in any of these coals. They were tested by boiling for some time the finely pulverized coal with water slightly acidulated with hydrochloric acid, in a flask from which the air was excluded by a current of carbon dioxide. The precaution of excluding the air is necessary, since pulverized iron pyrites boiled with water (or solution of sodium carbonate, as has been recommended for the determination of calcium sulphate) with access of air is readily oxidized, and the water reacts for sulphuric acid.

In the second series of analyses it will be seen that there is in each case an excess of total sulphur over what is necessary to form pyrites with the iron, and that there is not enough sulphur, as determined by bromine, to form pyrites with all the iron. This would seem to indicate that the sulphur is present in these coals, both as pyrites and as an organic constituent of the coal, and also that the iron is present, both in combination with sulphur and with silica or other inorganic constituents of the ash.

The foregoing determinations, while they are insufficient to throw much light on the effect of coking on the condition or the elimination of sulphur in coal, may not be without value in indicating a new line of investigation of coals and cokes.

In the coal *A*, which contains sulphur in considerable amount, both as metallic sulphide and as an inherent constituent of the coal, and which at the same time is low in volatile ingredients, it would seem as if the elimination of sulphur was limited to a portion of that existing as pyrites, and that the organic sulphur, if we may so call it, was not affected by the process of coking. This becomes apparent if the percentage of sulphur in the coke is calculated on the basis of the amount of coa required to make the coke.

In the other coals, low in pyrites and higher in volatile matters, there was an elimination of the organic sulphur to the extent of 20 to 45 per cent. It would be interesting to determine the effect of different methods of coking, and of the duration of the process on this elimination.

If we admit the presence of organic sulphur in coke, it is probable that no plan for its removal could be effective which would not involve the destruction of the coke itself. In the method of analysis given we are able to distinguish between the organic and inorganic combinations of sulphur in coke, and thus to determine the feasibility of its desulphurization.

It is interesting to note (more especially in coal *A*) that the ash of the coal which has been burned directly in oxygen contains much more sulphur than that from the same coal which has had its sulphur, in the form of pyrites, removed by bromine.

The analytical determinations in this investigation were made with great care by Mr. P. W. Shimer.

NATURAL FILTRATION AT BERLIN.

By Prof. Wm. Ripley Nichols.

Of recent years, every one in this section of the country, who is at all interested in water supply, has become more or less familiar with some of the disadvantages which are attached to surface-waters and especially to ponds (and lakes) and impounding reservoirs. The "pondy" taste and the brownish color acquired by water in streams which pass through marshy and peaty ground, the trouble caused by certain *algæ*, especially those which may be classed under the general head of *Nostocs*, the peculiar and unexplained tastes and odors with which some supplies are affected—these are well known, and, recently, from the researches of Professor Remsen,* it would seem that the fresh-water sponges may, by their growth and decay, create offence and impair the quality of an otherwise good water.

There are those who would have us believe that, on account of these difficulties, some of which may be overcome by artificial filtration, surface supplies should be abandoned and efforts made to procure a sufficient supply from the "ground-water" by the process of "natural filtration." By this method the water is taken by means of wells, "filter-basins" or galleries from a water-bearing porous stratum, generally in the immediate vicinity of a river or lake, and the water obtained is, as a rule, a mixture of the ground-water of the locality with more or less water derived from the neighboring stream or lake, the former usually predominating.†

* Report of the Joint Standing Committee on Water, on the Impurity of the Water Supply, with the report of Prof. Ira Remsen. Boston City Document 143, 1881 (Nov. 21).

† The various methods of utilizing the ground-water and a full discussion of the source of the water obtained may be found in the author's "Filtration of Potable Water," New York, Van Nostrand, 1879.

While in many localities a very good water can be thus obtained, it is apt to be somewhat limited in quantity and is usually harder than the surface water of the region. Every form of water supply has, however, its peculiar difficulties, and the ground water is not free from them. It is proposed in the present article to give an account of a serious difficulty which has occurred in connection with such a supply in Berlin, Prussia.*

Nature of the Trouble.—Since September, 1877, a portion of the Berlin water supply has been taken from the neighborhood of the "Tegeler See" by means of a series or line of 23 wells running parallel with the shore of the lake. The wells are from 50 to 100 metres distant from each other and fourteen of them are 4·5 metres in diameter, while the remaining nine have a diameter of 4 metres. The water of the several wells is pumped at first into a small reservoir with a capacity of 2215 cubic metres; the wells are covered and the reservoir is vaulted over and is surrounded by and covered with earth. Thence the water is forced to the Charlottenburg reservoir, between 6 and 7 kilometres distant; this is likewise covered and has a capacity of 12,000 cubic metres. Connected with this reservoir is a "well" or "suction chamber," from which the pumps take the water for the city supply, the pressure being regulated by a stand-pipe or, rather, by two connecting stand-pipes each 1·2 metres in diameter and about 50 metres high.

Shortly after the introduction of the water, complaints arose as to its quality, and investigation proved the difficulty to be two-fold. It is frequently noticed that water—and especially water from a driven

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* The sources of information are the following reports, besides various articles in the *Journal für Gasbeleuchtung and Wasserversorgung.*

Bischoff, Dr. Carl. Bericht über die chemischen und mikroscopischen Untersuchungen der Wässer der Tegeler Anlage, u. s. w. 8vo, pp. 71. 4 plates and 13 tables. Berlin, 1879.

Brefeld, Prof. Dr. O. und Zopf, Dr. W. Bericht über die Untersuchungen des Tegeler Wassers. (March 20, 1879.) 8vo, pp. 50. Berlin, 1879.

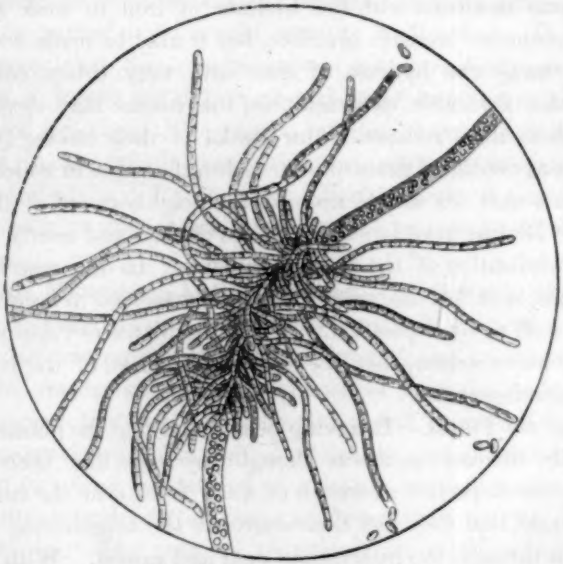
Zopf, Dr. W. Entwickelungsgeschichtliche Untersuchung über *Crenothrix polyspora*, die Ursache der Berliner Wassercalamität. 8vo, pp. 21, with 3 plates. Berlin, 1879.

Bischoff, Dr. Carl. Bericht über Untersuchungen filtrirten Brunnen und See wassers der Tegeler Station, u. s. w. (December, 1880.) 8vo, pp. 97. Berlin, 1881.

Finkener, Prof. Bericht über die Untersuchung des Tegeler Wassers. (Jan. 6, 1881.) 8vo, pp. 18. Berlin, 1881.

Gill, Henry. Bericht über die Untersuchung des Tegeler Wassers. (Jan. 20, 1881.) 8vo, pp. 25, with plate and diagrams. Berlin, 1881.

well—although apparently clear when first drawn, becomes turbid on standing and deposits an ochreous sediment which consists mainly of amorphous hydrated oxide of iron. This is generally due to the presence in solution of the protocarbonate or to some organic protosalt of iron, which—on exposure to the air—becomes oxidized and changed to an insoluble hydrated sesquioxide. This was one of the difficulties with the Tegel ground water, but the microscope showed that the ochreous sediment which settled from samples of the water and which accumulated in the reservoirs and in the pipes, especially in "dead ends," was by no means made up wholly of amorphous mineral matter, but consisted very largely of *algæ*, dead and alive.



Crenothrix Kühniana. 450:1.

Most noticeable among the *algæ* was the *Crenothrix Kühniana* (*Crenothrix polyspora, Cohn*). This plant was first discovered by Kühn in 1852, in the drains of a cultivated field in Silesia, but has since been found in wells in various parts of Germany and is probably very widely distributed. It has been called also *Leptothrix Kühniana* and *Hypheothrix Kühniana*, and its development was studied by Cohn and later, in connection with the Berlin trouble, by Zopf. In Berlin, it was found in the wells, in the reservoirs and in the service pipes in various stages of development and decay. The spores are minute

spherical or oblong bodies from one one-thousandth to six one-thousandths of a millimetre in diameter. From these spores, and by other means of development, the plants grow into comparatively long threads, each of which on examination is seen to be made up of a number of individual cells, end to end, inclosed eventually in a gelatinous sheath. The general appearance of a mass of these threads is shown in the figure, and the masses are sometimes a centimetre or more in diameter.*

The threads are at first, like the spores, transparent and colorless, but by the absorption of iron in some form or other they become colored from olive-green to a dark brown. They eventually, in many cases, become incrusted with the hydrate of iron to such an extent that their structure becomes invisible, but it may be made evident by dissolving away the hydrate of iron with very dilute chlorhydric acid. Under favorable circumstances, the plants may develop with great rapidity, and Professor Kühn speaks of their having frequently stopped up agricultural drain-pipes. Also, the pipes in which water is taken from a well, 10 metres deep, in the neighborhood of the Plötzensee, near Berlin, have in summer been choked and nearly filled up by the multiplication of the same organisms. In the reservoirs and in the "dead ends" of the service pipes they seemed to accumulate by growth as well as by deposition. While the plants develop more rapidly in the warm season, they are found at all times of the year in all stages of development.

Source of the Plants.—It having been found that the plants occurred in the wells themselves, it was thought by some that their presence was due to the imperfect exclusion of water from near the surface, and others thought that they had their source in the neighboring lake and were drawn through the intervening sand and gravel. With reference to the first point, Professor Finkener showed that there was no fault in the construction of the wells, but that, while the water from the upper layers became turbid on standing, this property was much more marked in the water of deeper origin. With reference to the second point, repeated and careful observations by different observers failed to discover the plant in the waters of the lake itself. (Bischoff, p. 43; Brefeld and Zopf, p. 5.) In fact the previous observations of Cohn

*The figure, which is adapted from Zopf, represents one of the thread-masses which has arisen by the germination of a number of spores still contained within the sheath. This is one of the methods according to which the plant develops.

and others would lead to the idea that the plant developed only in the dark, and Dr. Bischoff says: "On account of the entire absence of chlorophyll in the threads of the *Crenothrix* it seems to me justifiable to conclude that these organisms can exist only in the dark."* It seemed, then, that either the spores of the plant must in some way reach the wells from the outside and there develop, or else the plant must have its habitat in the ground itself. Accordingly, six driven wells were sunk to continually increasing depths in various localities in the neighborhood of the line of wells and, although the *Crenothrix* was not found at all depths in all of these driven wells, yet it did occur in each well at some depth or other. As it was found in all its various stages of development, the inference that the plant lived and grew in the ground itself would seem to be justified. It should be said, however, that this conclusion was not universally accepted, and Thiem, in a recent article† on ground-water supplies, speaks of it as an unsettled question. The reports of the observers seem perfectly clear, and in an examination which was made of the water from a number of wells in different parts of Berlin, the same plant was found in many cases, in one instance at a depth of more than 24 metres from the surface.

Remedial Measures.—At first, attempts were made to overcome the difficulty by diminishing the supply pumped, *i. e.*, by causing the water to pass less rapidly through the ground, and by frequent cleansing of the reservoirs; but these measures proved simply palliative, and it seemed that artificial filtration would be necessary. Various experiments were made in this direction, the most satisfactory being conducted in a filter constructed of masonry, vaulted over and covered with earth—resembling, in fact, the filters used on the large scale except in size. The area of the experimental filter-bed was nine square metres. It was found that, if the water was taken from the wells directly on to the filter, the filtered water—although at first clear—soon became turbid and deposited an ochreous sediment containing the *Crenothrix*. It was further found possible, by exposing the well

* Dr. Zopf found the *Crenothrix* in samples of the unfiltered and of the filtered water of the River Spree, but the Director of the Water Works, Henry Gill, says that the arrangements of the works are such that water from a deep well may become mixed with the river water, and of the occurrence of the plant in this well there was no doubt.

† *Journal für Gasbeleuchtung und Wasserversorgung*, xxiv (1881), p. 791.

water to the air, so that all the iron was oxidized and deposited before filtration, to obtain a filtered water which remained clear and in which the *Crenothrix* could not be found. It does not appear that experiments were made of exposing this filtered water to contact with iron as it would be if introduced into the service, so that it is not absolutely certain whether in the latter case the water was actually freed from spores or whether, spores being present, they failed to develop owing to the lack of the necessary conditions. Iron seems to be essential to the existence of the *Crenothrix*, and the threads, even when apparently colorless, are turned blue by ferrocyanide of potassium, thus showing the presence of iron. Of course the filter-sand was very much fouled and, on account of the difficulty of washing the sand thoroughly and the risk that the spores of the plant would eventually find their way into the lower part of the filters and thence into the service, it was thought best by those in charge of the works to abandon the wells altogether and to make use of water taken directly from the lake and filtered in the usual manner. It may be remarked, in this connection, that the *Crenothrix* has great vitality; thus, Dr. Zopf exposed a quantity in water out-of-doors from the first of January to the middle of February. The water was, of course, frozen and during the time the temperature fell as low as to —8°R. (11°F.), but after being thawed out the plants had, in a few weeks, contrary to all anticipation, revived again or new ones had grown from the spores.

Trouble in other Places.—The same trouble occurred in Halle, and it is stated that it was overcome by sinking other wells in a different locality. In the second locality the water was much harder and free from the *Crenothrix;* in fact, when it was mixed with water from the previous source it brought about the extermination of the plant; hence it has been inferred that the presence of a considerable amount of carbonate of lime is fatal to the plant.

Trouble in this Country.—No case precisely similar to that described above has come to my notice in this country, but I had occasion some time ago to examine somewhat cursorily a case having some points of resemblance. A town in the eastern part of Massachusetts was troubled with its water supply, the trouble consisting in an ochreous substance which was in the pipes and was discharged at the faucets, giving the water when first drawn a reddish appearance. When the water was allowed to stand it did not become turbid but the red particles contained in the water settled at the bottom in light flocculent

masses which the microscope showed to be made up largely of vegetable organisms. The source of supply was a small artificial and quite shallow pond, but at the time of my visit the water was not taken directly from the pond, but by means of an imperfectly constructed "filter-gallery" in the bed of the pond. As the water entered the main it was somewhat turbid, and if it was allowed to stand it deposited a rusty sediment, showing that the trouble did not originate in the pipes although it seemed to increase there.

Along the line of the main pipe, between the pond and the centre of the town, almost every hydrant when opened poured forth at first a stream of reddish-brown muddy liquid. After a time the water ran clear and I was informed that, although the pipes were flushed in this way by frequent openings of the hydrants, the same large amount of muddy water was as a rule always obtained. I did not in this case have the time to give to the study of the particular plant or plants which caused the trouble nor did I have the means to employ expert botanical assistance, so that I cannot say whether the *Crenothrix* was present or not. There was something of the same general character and that was all that it was necessary to know for the immediate purpose. Many of the *algæ* seem to attract hydrate of iron from water from which it is depositing;* even some of the larger *algæ*, the so-called *confervæ*, are often found incrusted with iron hydrate. This may be mainly a mechanical attraction, for even dead twigs and other solid objects become thus coated, but where the carbonate of iron is kept in solution by carbonic acid (as bicarbonate), the absorption of carbonic acid by the plant plays a part in the process by setting free the carbonate of iron which, however, is oxidized as fast as set free. It was noticed in Berlin that carbonate of lime was set free in a similar manner from the water in which it was kept dissolved by carbonic acid (as bicarbonate).

In closing, it may be worth while to say that the mere fact of the occurrence of a rusty sediment in a water does not prove the presence of the *Crenothrix* or of a similar *alga*. Thus, some time ago there was complaint of dirty water in a New England city which has an excellent water supply (surface water). The water came as a reddish mixture from the faucets and a rusty sediment settled in the vessels in

* Such, for instance, is the *Lyngbya ochracea* (formerly called *Leptothrix ochracea*) which is a rusty-colored, slimy plant found on the submerged iron of almost all water works. See *Farlow*, 1st *Annual Report Mass. State Board of Health, etc. Supp.* p. 151.

which the water was allowed to stand; the water was unfit for domestic use except after filtration. The trouble was found to be confined to the lowest section of the service, where the use of the water was not very great, and it was due, without doubt, to the settling into this lowest section of dirt and iron rust from the pipes, and the accumulation readily took place owing to the slowness of the current. A fire occurring in the region flushed the pipes so thoroughly that for a time the trouble was removed. Of course, frequent flushing of the pipes was the only remedy in a case like this.

SILK CULTURE IN THE UNITED STATES.

By Lorin Blodget.

A paper read at the Stated Meeting of the Franklin Institute, Wednesday, Feb. 15, 1882.

I appear before you at the request of your much respected Secretary, to state very briefly some points in the progress of the silk industry.

I have very short time given me to represent before your Association some of the more important features of this general question, and I will first ask your attention to the peculiarities of the silk fibre, as illustrated by microscopical examination, for the reason that these show, as I think, the most encouraging conditions as to quality, if not the superiority of the American silk fibre over that in general use.

The silk industry which I take to be the true significance of the words silk culture, as expressed on your invitation, is the third great industry of the textile class in this country, amounting to nearly $50,000,000 in value yearly, as now represented by actual manufactures, as compared with $250,000,000 in value of cotton manufactures, and $300,000,000 in value of manufactures of woolen and woolen mixed goods. The importation of silk goods is about $35,000,000 in value, making eighty-five millions of dollars as the value of silk goods entering into consumption in this country for a year.

This industry in silk manufactures has grown very rapidly from very moderate proportions ten or fifteen years ago to what I now state, or to forty-five millions at least, if we take the figures of the census of 1880.

In cotton and in wool we produce the raw materials of these vast

industries here, as a matter of course, but in silk we stand in the anomalous condition of producing as yet nothing of consequence in this country. Great as the country is, and great as the demand is for raw silk, we permit our superior natural advantages to remain unimproved, and we import about four million pounds of raw silk for manufacture here, nearly three millions of pounds reeled, and one million of pounds of spun and waste silk. Such is the unnatural and unnecessary condition of dependence of this industry on raw silk brought from the most remote sources, chiefly from Japan and China.

This great industry has more phases than I can represent, but one of the most important and interesting to the members of this Institute is the machinery required for silk manufacture. In this case, as in many similar cases, American genius is attaining results far in advance of those in use in the old world. We have in operation in the city of Philadelphia several new machines and combinations of machinery far superior in efficiency to those employed in Europe in similar branches of silk manufacture. One of these I have recently examined and illustrated, the power chenille cutter, invented in Philadelphia, and adapted to a wide range of fabrics.

Another important class of machinery is that of compound looms. There are in this city several hundred, each doing the work of ten, twelve or sixteen hand loom weavers in Europe, and but one person, perhaps, being required to two of these, each weaving from eight to sixteen silk webs of different widths, according to the width of the fringe or the width of the ribbon, or of narrow goods in any form. The same economy is effected in handkerchiefs, and it is to this superiority of design generally, in the construction and application of machinery to the smaller classes of silk goods, that the rapid development of this class of manufactures is due.

I can show you in one establishment at Fairmount one hundred of these compound looms, weaving and automatically cutting silk chenille and fringe of the most delicate kind, the processes being conducted in an automatic manner, and representing the economy we have attained, and the superiority of adaptation through which we have become successful in the manufacture of these goods.

Now as these processes are conducted almost entirely upon raw silk imported from foreign countries—Japan and China—it is very important to know whether the same principles of economy—the same adaptations of invention and skill, are or are not applicable to the

preliminary processes of growing silk, of reeling and of fitting silk from the cocoon to pass to the hand of the weaver.

You have before you, and I hope your Secretary will explain it, a reel almost as much improved in the matter of efficiency over the hand reels used in Italy as the machinery I have described to you—the chenille cutter and the power loom—are in the final manufacture of silk. You have the processes for growing silk and for reeling silk, to be examined and adapted, and if they are capable of the economies we suggest it becomes almost entirely unnecessary to ask whether we can grow silk in this country. That question is asked many times, and has been answered in the negative many times, yet I think, after all, it is a very absurd question. We may, with the same propriety, ask whether a farmer in this country can grow cotton at eight cents per pound. That is a question analagous to that of asking whether silk can be grown at $1.00 per pound for cocoons or $6.00 a pound for reeled silk.

It is not a question whether capital could stand the burden of a distinct and separate investment for this purpose, but whether the farmer could add the culture of silk to his other engagements and labor, and could live in part upon this as one of his resources. It is a question whether he could do so in cotton or in wool—for in fact there is no description of farming in the United States that would pay if conducted by the isolation of any one of these products. You could not, separately, grow 500 pounds of wool annually and make it pay, or 50 bales of cotton—and of course you could not grow 400 pounds of silk cocoons in this way and make it pay. It is by the combination of these or other products that farming is made profitable in this country, and in all other countries the same economy alone causes the production of silk to be made remunerative. If they can grow it in Italy, we can grow it here; and for the same reasons which apply in proving that if they can grow cotton in India, we can grow it in the Southern States. To-day we produce nearly $300,000,000 in value annually of raw cotton in the United States, often without profit to the careless planter, but with great profit to the country. I regard the conditions of growing silk as presenting circumstances much more favorable on the whole in this country, for reasons very easily stated. Silk raising where the trees are already grown does not require any considerable investment of capital, nothing for the purchase of land, or of the purchase of fer-

tilizers for the soil, or for the mules indispensable on the Southern plantation. It can be done by any one member of any family or by as many more as may choose to engage in it. It is not field work, and therefor not labor to be paid for in cash.

It is very easy to prepare for it on any of the farms of the interior or near the cities. It is not wholly new to urge the production of silk here; it has been recommended many times and by high authority. I have in my hand the proof that the Philosophical Society of this city started a fund for the growing of silk at an early day and to which the most eminent citizens of this city contributed in 1770, and the statement before me alleges that this society now holds in trust a fund contributed for that purpose, which I hope may be made available. Before referring to the recent movement by which the silk manufacture has been most effectively encouraged, I wish to show you some samples of raw silk made here by our own people—the Women's Silk Culture Association of Philadelphia.

A great deal of very inferior silk from India and other remote countries is now used—not so much here as in Europe. Here are specimens of it. The product of an inferior class of moths, which may be generally distinguished as the *Attacus*, whereas the true silk moths, the *Bombyx*, differ widely. (A moth with a black cocoon exhibited.) I have examined many of these cocoons and their fibres under the microscope. I find that the black cocoon yields a flat, coarse, apparently hollow fibre, inferior in every respect to the true silk. I can take many descriptions of silk goods sold in this country to-day which contain this inferior fibre. From a few cocoons obtained some months ago I had reeled immediately the specimens now shown and which have not been taken from the case since the reeling was done, and this silk presents a striking contrast. I have here an imported specimen of raw silk that has not been taken from the envelope, sent as the best grown in France, yet it is certainly not better than the sample reeled here, and most persons would pronounce it inferior in strength and elasticity of fibre.

Your Secretary gives me some silk reeled upon the new reel, constructed under his direction for the Women's Silk Culture Association, which I think you will find presents some characteristics of superiority as compared with any of the others, and which shows that the silk grown here from ordinary cocoons in the city of Philadelphia is at least equal to the best. Of the samples I have before me, derived

from various sources, those reeled here in Philadelphia are the best by all the tests that I can apply.

I should not have given so much attention to this point of distinction, although it is a very important one, except that in the *Paterson Guardian* of February 10th there appears an article especially discrediting American silk. In this article several specious and apparently plausible reasons are given why silk cannot be economically grown here, but its main point is in the assertion that American silk is inferior, and not fit for the best woven fabrics. It is also asserted that the quantity grown here is scarcely sufficient even for the single dress now in progress of manufacture to be presented by the Association to Mrs. Garfield. I will not repeat the language of this most unjust and untruthful criticism, but I will answer it in part by saying that there were five thousand pounds of cocoons grown in the last year, now waiting for anybody that will set up a reel. The country was not scoured to obtain the quantity now used; it has been obtained without difficulty, and it is not true that it is of an inferior quality. All the silk produced by the Ladies' Association is equal, and much of it superior, to that imported as the best Italian. I have no doubt of its quality, and I have examined it critically on many occasions.

I have here microscopic tests of perhaps ten or twelve different silk fibres and fabrics, and in all cases this form of examination shows precisely what character of fibre is employed in the manufacture. In examining the thread of which a certain class of fringes is made—it is found to be inferior—it is waste silk and quite worthless for wear. All these fabrics disclose their qualities under the microscope as distinctly as if the fibres were a sixth of an inch in diameter. I speak of this because it is often said that the American raw silk product is itself as far behind in quality, and therefore as far inferior in capacity for fine manufactures, as the state of the manufacturing industry was a few years since said to be behind that of France. It was then insisted that it would be impossible ever to produce superior goods. I will guarantee that where the same number of fibres are reeled from the cocoon in the raw silk reeled here, taking an average of the specimens, that the fabric ultimately produced will weigh heavier in dress goods, or in handkerchiefs, than if made of the same number of cocoon fibres sent here as Italian. If this is true, it is sufficient to show that the silk producing industry is not likely to fail here.

As to the manner in which the change shall be brought about, and

the introduction of this industry of raw silk shall be secured, I hope you will allow me to call to your attention the work of the organization called the "Women's Silk Culture Association of the United States" which has, since April, 1880, conducted a correspondence with several hundred persons in different parts of the United States, and in the way of suggestion, of encouragement, of instruction, and by all the methods available to them, have made the growth of silk a subject of national pride and of public economy. More than all, they have made it a matter of especial benevolence to many who suffer for want of employment, and for want of practicable methods by which their time can be turned into money. I think these ladies deserve the highest measure of honor that can be given them, whether they succeed in their attempt as a business enterprise or not. This is not attempted in the ordinary sense except that they hope to make the account of receipts and expenses balance at the end of the year, and this they have done. The most important question is, whether their efforts, impartial as they are, public-spirited in the best sense, and prompted by the highest benevolence, as well as pursued with the most persistent energy, are likely to attain their object.

In my judgment their prospects now offer great encouragement to all who have been associated with their undertaking. No taint or private profit or speculation attaches to it, nor has it any real obstruction likely to defeat its objects. They are now closing their second, and entering upon their third year of active labor, and the demand all over the country is very great for the information and the instruction which they give to all applicants.

In urging the public to give this work their attention I have no other purpose than to discharge the economic duties which I have, to a certain extent, assumed for a great many years. I earnestly insist that an industry like this ought to receive the encouragement of the people, the encouragement of the Legislatures of the States, and the encouragement of Congress. There is nothing in the way of developing an industry that will at once bring to the Central and Southern States a great accession to the resources of the people, and a help rather than a hindrance to the cotton industries of those States.

The Secretary at the close of Mr. Blodget's remarks gave, by request, the following explanation of the improved iron frame silk reel lately constructed for the Women's Silk Culture Association, viz.: A year or so ago the association, after considerable trouble, succeeded

in getting a pattern of the reels which were said to be in use in France and Italy, a clumsy affair, all of wood, which stood upon four legs, like a table. After it had been in use a little while it warped and became so troublesome to use that it occurred to some of the members of the Advisory Board to have a mechanical reel constructed of metal, which would work more accurately, and represent in an improved form the best ideas we had upon the subject. This was finally decided upon, and after some consultation the speaker was requested to secure the services of an expert machinist to construct such a reel. Mr. Hugo Bilgram, a member of the Institute, was requested to undertake the work, and the result of his intelligent comprehension of the subject you see in the admirable, light, easy and rapid running reel, which I take pleasure in showing you this evening, and which I believe has been found eminently satisfactory. It is constructed entirely of metal; it is very light and compact, and devised in such a manner that it can be closed together in a very compact form when not in use, or when it is to be removed from place to place. While there is no new mechanical feature in it, it represents generally the construction of the hand reels of France and Italy.

The silk is wound upon the reel, and the motion is communicated to the reel by hand. The driving wheel is grooved, and motion is transmitted to a smaller grooved pulley in the shaft of the reel, the proportions between driving and driven pulley being as 4 to 1. The traverse which effects the crossing of the strands on the reel is given by an open cam on the driving shaft. This engages with a bell-crank lever, connected with a brass sleeve upon a cross bar above, which slides back and forth with the motions of the lever arm. The guides through which the silk threads pass to be wound on the reel are attached to this sleeve, and they are thus given the required crossing.

The reel works with great accuracy, and without jar or lost motion, and it has proved to be most satisfactory as a first effort to construct such a machine in metal.

The skilled reeler employed by the association is enabled to reel more than double the quantity of silk upon this than upon the old wooden reel, a result highly gratifying to the association, and one that has a very important bearing on the question of the profitable reeling of silk by hand in the United States.

ACTION OF FREE MOLECULES ON RADIANT HEAT, AND ITS CONVERSION THEREBY INTO SOUND.

By J. Tyndall, F.R.S.

Abstract of the Bakerian Lecture for 1881.

The lecture opens with a brief reference to the researches of Leslie, Rumford, and Melloni. The labors of Tyndall and Magnus, as far as they bear upon the present subject, are then succinctly sketched, their points of difference being signalized and briefly discussed. This preliminary sketch is wound up by a reference to a recently published paper by Lecher and Pertner, who, while supporting the lecturer in the matter of gases, dissent from him in the matter of vapors. These investigators are especially emphatic in affirming the neutrality of aqueous vapor to radiant heat. Following Magnus, they refer Tyndall's results to what Magnus calls "vapor-hesion," that is to say, to the condensation of the vapors on the surfaces of the plates of rock-salt used to close the experimental tube, and on the interior surface of the tube itself.

In November, 1880, the lecturer's investigations in this field were resumed. Former experiments were repeated and verified with divers sources of heat, and with various experimental tubes—some polished within, and others coated inside with lampblack. The results obtained with the one class of tubes are substantially the same as those obtained with the other.

But even a coating of lampblack may be supposed to reflect a certain amount of heat, hence the desirability of an arrangement whereby internal reflection should be entirely abolished. This was accomplished in the following manner: A spiral of platinum wire, rendered incandescent by a voltaic current of measured strength, was chosen as a source of heat. An experimental tube 38 inches long and 6 inches in diameter had two circular apertures at its ends, closed by transparent plates of rock-salt, 3 inches in diameter. The tube was furnished with three cocks—one connected with a large Bianchi's air-pump; another with a purifying apparatus; while through the third vapors and gases could be admitted. Prior to entering the tube, the calorific rays were sent through a very perfect rock-salt

lens, by means of which an image of the spiral was formed on the most distant plate of rock-salt. To obtain the image with clearness, the spiral was first rendered highly luminous, and afterwards reduced, by the introduction of resistance, to the required temperature. In this way a calorific beam was sent along the axis of the experimental tube without at all impinging upon its interior surface. No reflection came into play; no absorption by hypothetical liquid films, coating the internal surface, could occur; and yet experiments made with this arrangement entirely confirmed the preceding ones, wherein by far the greater quantity of heat which reached the pile had undergone reflection.

When the source of heat was changed to a carefully worked cylinder of lime, a portion of which was rendered incandescent by an ignited stream of coal-gas and oxygen, the results were confirmatory of those obtained with the spiral. The order of absorption in both cases was the same, the only difference being that the fractional part of the total radiation absorbed in the case of the lime-light was less than that absorbed in the case of the spiral.

To condense a radiation from the lime-light, concave mirrors were sometimes employed, and sometimes rock-salt lenses. The results in both cases were identical.

An experimental tube of the dimensions here given was employed by the lecturer to check his results more than ten years ago. Its interior surface was rough and tarnished, and when warmed dynamically by the entrance of a gas its power as a radiator enabled it to disturb, to some slight extent, the purity of the results. To obviate this, the experimental tube recently employed was provided with an internal silver surface, deposited electrolytically and highly polished. By this arrangement the radiation of the tube itself, as well as its absorption, was rendered quite insensible.

The rock-salt plates used to close the experimental tube, and on which liquid films are alleged to be deposited, remain to be examined. In this case also an *experimentum crucis* is possible. If the observed absorptions be due to such liquid films, then the separation of the salts more widely from each other, the space between them being copiously supplied with vapor, ought to produce no effect; but if the absorption, as alleged by the lecturer, be the act of the vapor molecules, then the deepening of the absorbing stratum ought to produce an augmented effect. For many gases and some vapors this

problem was solved as far back as 1863. By means of an apparatus then described, polished plates of rock-salt could be brought into contact with each other, and then gradually separated, until the gaseous stratum between them was some inches in depth. With sulphuric ether vapor the distance between the plates being $\frac{1}{20}$ of on inch, an absorption of 2 per cent. was observed. With a thinner stratum, or a weaker vapor, even this small absorption vanished; while in passing from $\frac{1}{20}$ of an inch to 2 inches the absorption rose from 2 per cent. to 35 per cent. of the total radiation. Such experiments, recently verified, entirely dispose of the hypothesis that liquid films were the cause of the observed absorption.

The "vapor-hesion" hypthesis involves the assumption that liquids exert on radiant heat an absorbent power which is denied to their vapors. It assumes, in other words, that the seat of absorption is the molecule considered as a whole, and not the constituent atoms of the molecule. For were the absorption intra-molecular, the passage from the liquid to the vaporous condition, which leaves the molecules intact, could not abolish the absorption. So far back as 1864 the lecturer had proved that when vapors, in quantities proportional to the densities of their liquids, were examined in the experimental tube, the order of their absorptions was precisely that of the liquids from which they were derived. This result has been recently tested and verified in the most ample manner by means of the apparatus in which internal reflection never comes into play. It furnishes, therefore, the strongest presumptive evidence that the seat of absorption in liquids and in vapors is the same.

As a problem of molecular physics it was, however, in the highest degree desirable to compare together *equal* quantities, instead of proportional quantities, of liquids and vapors. Highly volatile liquids alone lend themselves to this experiment, for only from such liquids can vapors be obtained sufficient, when caused to assume the liquid form, to produce layers of practicable thickness. Two cases, however, have been very fully worked out, the substances employed being the hydride of amyl and sulphuric ether. Careful and exact experiments, many times repeated, lead to the result that when the number of molecules traversed by the calorific rays in the vapor is the same as that traversed in the liquid, the absorptions are identical. In the silvered experimental tube, which, as stated, is 38 inches long, hydride of amyl vapor, at a mercury pressure of 6·6 inches, is equivalent to a

liquid layer 1 millim. in thickness, while a vapor column of sulphuric ether, of the same length, and 7·2 inches pressure, would also produce a liquid layer 1 millim. thick.' The experiment has been made with the utmost care, both with the lime-light and the incandescent platinum, with the result that it is impossible to say that there is any difference between the vapor absorption and the liquid absorption. In the face of such facts the "vapor-hesion" hypothesis, as an explanation of the results published by the lecturer, cannot be sustained.

On the 29th November, 1880, he had the pleasure of witnessing, in the laboratory of the Royal Institution, the experiments of Mr. Graham Bell, wherein a concentrated luminous beam, rendered intermittent by a rotating perforated disk, was caused to impinge upon various solid substances, and to produce musical sounds. Mr. Bell's previous experiments upon selenium naturally led him to conclude that the effect was produced by the luminous rays of the spectrum. The contemplation of these experiments produced in the lecturer the conviction that the results were due to the intermittent absorption of radiant heat. He was experimenting on vapors at this time. Substituting in idea gaseous for solid matter, he clearly pictured the sudden expansion of an absorbent gas or vapor at every stroke of the calorific beam, and its contraction when the beam was intercepted. Pulses far stronger than those obtainable from solid matter would probably be thus produced, which, when rapid enough, would generate musical sounds. The intensity of the sound would, of course, be determined by the absorptive power of the gas or vapor.

This idea was tested on the spot. Placing sulphuric ether in a test-tube, and connecting the tube with the ear, the intermittent beam was caused to fall upon the vapor above the liquid. A feeble musical sound was distinctly heard. Formic ether was tried in the same way, and with the same result. Bisulphide of carbon was then tried, but the vapor of this liquid proved incompetent to generate a musical sound. These results, which were in perfect accordance with those previously enunciated by the lecturer, were first made public during a discussion at the Society of Telegraph Engineers on the 8th of December, 1880. (*Journal of Telegraph Engineers*, vol. 9, page 382.)

It was obvious, however, that the arrangement of Mr. Bell—a truly beautiful one—was not suited to bring out the maximum effect. He had employed a series of lenses to concentrate his beam, and these, however pure, would, in the case of transparent gases, absorb a large

portion of the rays most influential in producing the sound. The lecturer, therefore, resorted to lenses of rock-salt and to concave mirrors silvered in front. He employed various sources of heat, including that of the electric lamp. The lime-light he found very convenient. With the lime-light and concave mirror, sounds of surprising intensity were produced by all the highly absorbent gases and vapors. Among gases chloride of methyl was loudest. Conveyed directly to the ear by a tube of india-rubber, the sound of this gas seemed as loud as the peal of an organ. Abandoning the ear-tube, and choosing a suitable recipient for the gas, the sounds were heard at a distance of 20 feet from their origin. As regards intensity, the order of the sounds, in gases, corresponds exactly with the order of their absorptions of radiant heat.

Among vapors sulphuric ether stands highest, this result being in part due to the great volatility of the liquid. But the intensity of the sound is by no means wholly dependent on volatility. The specific action of the molecules on radiant heat is as clearly shown in these experiments as in those previously conducted with the experimental tube and thermopile. Upwards of eighty vapors have been tested in regard to their sound-producing power.

With regard to aqueous vapor, whose action upon radiant heat even the latest publications on this subject describe as *nil*, it was especially interesting to be able to question the vapor itself as to its absorbent power, and to receive from it an answer which did not admit of doubt. A number of bulbs about an inch in diameter were placed under the receiver of an air-pump, with a vessel containing sulphuric acid beside them. When thoroughly dry they were exposed to an intermittent beam. The well-dried air within the bulbs proved silent, while the slightest admixture of humid air sufficed to endow it with sounding power. Placing a little water in a thin glass bulb, and heating it nearly to its boiling point, the sounds produced by the developed vapor are exceedingly loud. The bulbs employed in these experiments are usually about a cubic inch in volume. They may, however, be reduced to one-fiftieth or even one one-hundreth of a cubic inch. When a minute drop of water is vaporized within such little bulbs, on their exposure to the intermittent beam loud musical sounds are produced.

It is to be borne in mind that the heat employed in these experiments, coming as it did from a highly luminous source, was absorbed

in a far smaller degree than would be the heat from bodies under the temperature of incandescence.

To render the correlation of sound-producing power and adiathermancy complete, all the gases and vapors which had been exposed to the intermittent beam were examined as to the augmentation of their elastic force through the absorption of radiant heat. A glass cylinder, 4 inches long and 3 inches in diameter, had its ends closed with transparent plates of rock-salt. Connected with this cylinder was a narrow U-tube, containing a colored liquid which stood at the same level in the two arms of the U. The cylinder could be exhausted at pleasure or filled with a gas or vapor. When filled, the sudden removal of a double silvered screen permitted the beam from the lime-light to pass through it, the augmentation of elastic force being immediately declared by the depression of the liquid in one of the arms of the U-tube and its elevation in the other. The difference of level in the two arms gave, in terms of water-pressure, a measure of the heat absorbed. With the stronger vapors it would be easy with this instrument to produce an augmentation of elastic force corresponding to a water-pressure of a thousand millimetres. As might be expected, the intensity of the sounds corresponded with the energy of the absorption, varying from "exceedingly strong," "very strong," "strong," "moderate," "weak," to "inaudible." In this connection reference was made to the interesting experiments of Professor Röntgen, an independent and successful worker in this field.

In conclusion, the lecture draws attention to the bearing of its results upon the phenomena of meteorology. The views of Magnus regarding the part played by mist or haze are referred to and attention is directed to various observations by Wells which are in opposition to these views. The observations of Wilson, Six, Leslie, Denham, Hooker, Livingstone, Mitchell, Strachey, and others are referred to and connected with the action of aqueous vapor upon solar and terrestrial radiation. Many years ago the lecturer sought to imitate the action of aqueous vapor on the solar rays by sending a beam from the electric light through a layer of water, and afterwards examining its spectrum. The curve representing the distribution of heat resembled that obtained from the spectrum of the sun, the invisible calorific radiation being reduced by the water from nearly eight times to about twice the visible. Could we get above the screen

of atmospheric vapor, a large amount of the ultra-red rays would assuredly be restored to the solar spectrum. This conclusion has been recently established on the grandest scale by Professor Langley, who on the 10th of September wrote to the lecturer from an elevation of 12,000 feet on Mount Whitney, "where the air is perhaps drier than at any other equal altitude ever used for scientific investigation." An extract from Professor Langley's letter will fitly close this summary: "You may," he says, "be interested in knowing that the result indicates a great difference in the *distribution* of the solar energy here from that to which we are accustomed in regions of ordinary humidity, and that while the evidence of the effect of water vapor on the more refrangible rays is feeble, there is, on the other hand, a systematic effect, due to its absence, which shows, by contrast, its power on the red and ultra-red in a striking light. These experiments also indicate an enormous extension of the ultra-red rays beyond the point to which they had been followed below, and being made on a scale different from that of the laboratory—on one indeed as grand as nature can furnish—and by means wholly independent of those usually applied to the research, must, I think, when published, put an end to any doubt as to the accuracy of the statements so long since made by you, as to the absorbent power of water-vapor over the greater part of the spectrum, and as to its predominant importance in modifying to us the solar energy."—*Proceedings Royal Society.*

Use of Petroleum as Fuel in Russia.—Upon the Balachanskoi Railway the locomotives are heated with crude naphtha, which is introduced into the tender as it comes from the wells, and there have been no accidents resulting from its use. All the ships upon the Caspian Sea are heated exclusively with the liquid combustible, the cost being only half as great as that of coal. Experiments which have been made upon some of the railways show that a kilogramme of naphtha is equivalent to 8½ kilogrammes of wood, although the theoretic heating power is only three times as great. The use of petroleum with injectors for introducing it into the furnaces is very convenient—the combustion can be regulated with the greatest ease; the furnaces last much longer on account of the absence of sulphur; there are no cinders, smoke or sparks, and the work of the stokers is greatly simplified.—*Soc. des Ingen. Civils.* C.

Security against Counterfeiting.—N. J. Heckmann adds five per cent. of cyanide of potash and sulphide of ammonium to the sizing water, and passes the sized paper through a thin solution of sulphate of magnesia or copper. If any attempt is made to remove writing from such paper by means of acids or alkalies the tint of the paper is immediately changed. If any erasures are attempted the coloring matter, which is only upon the surface, is removed.—*Dingl. Jour.* C.

Planets and Sun Spots.—Adolph Duponchel has presented a communication to the French Academy upon the agreement of the curve of sun spots with the actions resulting from the eccentricity of the principal planets. Faye has criticised the paper, and Duponchel has answered his criticisms by certain predictions, which he submits as tests of his theory. He thinks there will be an increase of the mean temperature in any given place during the twelve years to come over that of the twelve years which have just passed. Uranus and Neptune are about receding from their perihelia, and he anticipates an effervescence in the solar atmosphere, analogous to that which occurred between the years 1716 and 1725. He thinks this will be accompanied by an increasing frequency of spots, of which the maximum will occur, not in 1882 as is generally supposed, but between 1888 and 1892.—*La Nature.* C.

Observations in the Clouds.—The French society of aerial navigation has entrusted MM. Dutèt-Poitevin and du Hauvel with different balloon observations, among which was the study of the formation of clouds, taking into account the vapor tension in neighboring strata of air but of different temperature, and also the study of the release of the latent heat of vaporization at the moment of precipitation. The observations yielded the following results: 1. The clouds are formed in the zone of mixture of two layers of air saturated mith moisture. 2. The clouds originate in the warm layer and dissolve in the colder layer. 3. They move in the direction of the belt of air which has the highest temperature. 4. The winds which are observed at the surface of the ground, which are only effects of the reaction of the principal wind, may have a height of several hundred yards, and may have different directions in neighboring localities, while the upper current has a great regularity of direction and intensity.—*Comptes Rendus.* C.

Periodic Variations of Glaciers.—M. F. A. Forel, of Morges, presented to the first general meeting of the Swiss Society of Natural Science his investigations upon the periodic variations of glaciers. The present remarkable period of glacial retreat began about 1840 in some places, but the Unteraar glacier did not begin to diminish until about 1871. The period is now coming to an end and many of the glaciers are beginning to increase again. The differences of length are immediately traceable to periodic variations in the velocity of flow, which are due to corresponding variations in the thickness of the glacier. These are due partly to differences of snow-fall upon the summits, partly to variations in the summer heat; the latter cause has probably only secondary influence. The retreat which is just ending is attributable to a deficit of snow which dates back from 40 to 60 years and a series of warm summers for the past 20 years.—*Les Mondes.* C.

Influence of Dust upon Explosions.—M. L. Aguillon gives a summary of the principal facts which seem to have been established by Prof. Abel's experiments upon the influence of dust on mine explosions. One of the most sensitive of the Seaham powders contained the least proportion of carbon, and more than one-half of its material was incombustible. The special experiments which were suggested by this observation showed that powders which are entirely incombustible, and are not susceptible of any chemical change through the action of flame, become very dangerous when brought in contact with a mixture of air and fire-damp. This effect seems to be attributable, at least in part, to the fact that the particles, in passing through a flame, become incandescent so as to localize and increase the heat. One of the powders formed an explosive mixture in air containing only 2 per cent. of gas, and when a current of air was blowing with a velocity of only 5 decimetres (19·7 inches) per second, one and a half per cent. of gas was sufficient to make the mixture explosive. The coal dusts in mines not only develop and extend explosions, but through their rapid inflammability and their disposition to remain suspended in currents of air, but they may also intervene as a means of propagating a flame rapidly as far as they extend, and rendering a proportion of fire-damp explosive which would not otherwise be dangerous.—*Ann. des Mines.* C.

Tunnel of the Arlberg.—The length of the tunnel is to be 10,270 metres (6·382 miles). The culminating point is to be 4205 metres (2·611 miles) from the eastern extremity, at an altitude of 1310 metres (1332·63 yards) above the Adriatic. The work was begun in June, 1880. Two perforators are used; at the eastern end the Ferroux machine, which was employed in the St. Gothard tunnel, acting by percussion and moved by compressed air; at the west end is the Brandt machine, which is moved by water under pressure, and drills by boring. It had given excellent results at Pfoffensprung, upon the Swiss side of the St. Gothard line, and the inventor guaranteed an advance of at least two metres per day, a guarantee which has been largely exceeded. The simultaneous employment of the two engines is especially interesting, since it will allow a comparison under identical conditions, and will have a great influence upon the choice of methods in the piercing of future tunnels. The ventilation will be made by a separate apparatus, distributing air under a low pressure, through tubes carried into the neighborhood of the workmen. The specifications provide for a minimum volume of 150 cubic metres per minute for each workman. At St. Gothard the supply rarely reached 100 cubic metres.—*Jour. de la Soc. Autrich.* C.

Curious Acoustic Phenomenon.—M. Reulaux reports a singular instance of the production of sound by natural causes. During a hunt upon the Rõderbacherthal he passed through a valley, broad upon the eastern side, but narrowing rapidly towards the west, so as to form a kind of defile. The wind was blowing from the southwest, and the observer was marching upon the eastern declivity, when he seemed to hear repeated strokes of a fine deep-toned bell. There was no bell in the neighborhood, and other sounds which he heard soon proved that the phenomenon was meteorological. The sounds increased in intensity, and then diminished after having passed through a maximum. They resembled, at times, those of an organ, and at other times those of a harp or violin. At the entrance of the defile, from which the sounds seemed to come, there arose a strange agitation of the air, when the sounds became confused, and some of the notes suddenly ceased. M. Reulaux supposes that currents of air were forced through the gorges, and that the sound was due to a conflict between the exterior and interior air, which produced musical vibrations. There was a very marked difference of temperature between the upper and

lower portions of the valley, so that the upper cold current pressed upon the lower and warmer air, thus closing the gorge so as to make a kind of tube. There appeared to be no wind except in the lower part of the gorge.—*Les Mondes.* C.

New Treatment of Distillery Refuse.—The weak liquors which escape from the distilleries injure the water of streams and springs, and in some cases become a medium of infection for the whole neighborhood. MM. Gaillet and Huet add to the liquors perchloride of iron in suitable proportion, mixing the ingredients thoroughly. After the first reaction is completed milk of lime is stirred in, which precipitates the sesquioxide of iron, carrying with it almost all the organic matter. The remaining liquid is perfectly clear, colorless, harmless, not liable to fermentation and offering no inconvenience to the public health. The precipitate forms a manure, very rich in nitrogen and in phosphoric acid. The sale of the manure not only frees the refuse from being a burden upon the industry, but also makes it a source of profit.—*Les Mondes.* C.

Relation of Atmospheric Resistance to Temperature.—Hirn has presented a memoir to the Belgian Academy in which he gives the results of numerous experimental researches upon the relation which exists between the resistance of the air and its temperature. The hypothesis of Clausius, upon the constitution of gases, was supposed to furnish the means of calculating their resistance *a priori*, but upon attempting to establish the formula experimentally Hirn was unable to obtain the results which he anticipated. The memoir was submitted to the examination of Messrs. Folie, Van der Mensbrugghe and Melsens. The committee were unanimous in recommending its publication and in expressing the belief that its startling conclusions would be likely to awaken much profitable criticism and discussion, but Melsens was the only one who was prepared to adopt Hirn's conclusions and to admit that they would be likely to require a re-examination of some of the most important conclusions of thermodynamics. Hirn thinks that he has demonstrated that temperature has no influence upon the resistance of gases, that gaseous temperature and pressure cannot be explained by the movements of material atoms, and that it is impossible to give any satisfactory explanation of molecular phenomena without assuming an immediate dependence upon spiritual influence.—*Bull. de l'Acad. de Belge.* C.

Action of Light upon Oxygen.—J. Dessans has contrived an apparatus for governing the admission of the radiations from a Drummond light into a jar of oxygen, and he concludes, from experiments which he has frequently repeated, that light effects a direct transformation of oxygen into ozone. In the course of his experiments he sometimes used the oxygen as pure as possible, and in other cases he introduced substances which are easily oxidizable, so that they might readily combine with the ozone. Both methods of experimenting led to the same result.—*La Nature.* C.

Book Notices.

EXPERIMENTAL RESEARCHES INTO THE PROPERTIES AND MOTIONS OF FLUIDS, with theoretical deductions therefrom. By Mr. Ford Stanley. 8vo. London: E. & F. N. Spon, 1881.

One of the most elaborate and full studies, especially experimental, on this branch of physics to be found in English. Both in the collection of imperfectly known, and in the publication of entirely new and curious phenomena in minor experimentation, the book is unexampled.

In the latter regard some striking exhibitions are made. On page 72 is shown the extent of surface of disturbance of water by the effort of capillarity of tubes of various diameters by reflection from the water surface itself. On page 144 is shown how the general disturbance of a river current may be observed by a free circular floating tablet. On page 187 and following will be found a series of experimental yieldings of a minie ball, from the plasticity of its material—lead—against the resistance offered to its passage when discharged into water, by the mass of water, where the lead flattens and introverts itself into a coniod of hyperboloidal character approaching towards the whirl-ring which proceeds from a drop of colored water similarly but less forcibly projected into clear water—a series of illustrations ending in the rings which are deposited concentrically in the bottom of a shoal basin when consecutive drops of aniline solution are allowed to fall in still water. On page 238 the action of Venturi's cone in accelerating the velocity of an escaping jet is shown by a plane of discharge between flat glass plates with Venturi curves bounding the margins. Beside numerous

other interesting and pretty experiments. [The author is requested to test experiment, page 272, with one of the streams of colored water, when the writer thinks he will find the jets not to cross each other actually, but merely to do so apparently, and that it is a case of translation of motion.]

With all this nicety of experiments it cannot be said that the discussion of them in all cases reaches to theoretical deduction; frequently it scarcely passes the point of sentimental consideration. It may be admitted, with the author, that the theoretical, mathematical discussions of fluid properties and motions have not met happy solution on the supposition of linear movement in any vessel, tube or canal, and that the rolling effects (whirls) which, as far as we know, were first asserted by Darcy are the important, or at least *a* very important element to be investigated and reduced to *mathematical* expression. And it may be, also, that the *considerations* presented in this book have their place in indicating the direction of mathematical inquiry; but yet it is sure that we do not, as the result of Mr. Stanley's studies, come any nearer to the ability to form a correct theory of the motions of fluids than we were before. Weisbach, Rankine and Francis give practical results in better form for utility. It seems certain that their formula should have some different construction to be general, and that just such a study as this will show how to arrange or express them, only throughout this work no effort is made to go beyond the exhibition of phenomena in the direction of positive knowledge. The closest observation of the time-keeping qualities of a hundred watches would not of itself allow one to be made.

A writer in science is not at liberty to change an accepted name, because it does not express to his or to any mind most fully the property. Gelatinity is only a word. Viscosity expresses the internal resistance of a fluid quite as well, there might be an argument that it does better than gelatinity, but so long as the meaning is evident in the connection why not leave the word and pursue the study to the cause and not the name? Similarly, whirls and by-whirls, when vortexes are generally known. Possibly a theory of minor vortexes to explain the rolling or riband effects of surface contact might find a new name in by-whirls, when the mathematical exposition should complete the experimental development.

Passing from the narrative of observation which forms the first section or about one-half the book; to the "discussion of natural phenomena

in connection with previous propositions," it may be questioned if the *deductions* of Section I can be allowed as conclusive in governing the cosmic propositions of Section II. The writer of this notice thinks the author in common with many other book writers and storm authorities fails to appreciate the extreme thinness of the layers of atmosphere and of water in comparison to the superficial extent with which they have to deal and the enormous preponderance of local over general disturbances. Beside this, in the matter of aerial currents, there remains a remark of Sir John Leslie, seventy or eighty years since, on the positive direction of a current of air and the effect of the globular form of the earth when bodies in tangential movement crossed any locality. Together with some general assertion that a cloud or rain is at all times an ascending current, and clear weather a descending current of more or less intensity. On the whole it is hard to discern where the field of usefulness of this second section comes in, for it certainly lays down no laws of practical application.

Still the book must be recommended to students in physics as an extremely valuable contribution to science likely to awaken interest and induce study. R. B.

Franklin Institute.

HALL OF THE INSTITUTE, Feb. 15, 1882.

The stated meeting was called to order at 8 o'clock P.M.

There were present 122 members and 36 visitors.

The minutes of the last meeting were read and approved.

The Actuary submitted the minutes of the Board of Managers and announced that at the last meeting of the Board 10 persons were elected members of the Institute; he also reported that, by reason of the election of Mr. Frederick Graff to the office of Vice President, a vacancy was thereby created in the Board.

The Chemical Section presented its monthly report, which was read by the Secretary.

The President announced the first paper of the evening, by Mr. Grimshaw, on the determination of the "Driving Power of Belts." An abstract of his remarks, and the discussion thereon, will be found on page 174.

Mr. Lorin Blodget read a paper on "Silk Culture in the United States," for which see page 216.

At the request of Mr. Blodget the Secretary described the "Improved Silk Reel" of the Women's Silk Culture Association, designed and constructed by Mr. Hugo Bilgram, a member of the Institute. While there is no radical departure in its construction from the old forms of hand-reels, the new reel appears to embody every desirable feature that a hand-reel should possess. It is constructed entirely of metal (excepting the bars of the reel), and a skillful operator is enabled to reel upon it at least twice as much silk from the cocoons as upon the ordinary wooden hand-reels.

The report of the Secretary included a *resumé* of progress in Science and the Industrial Arts during the year 1881, and the exhibition and description of a number of mechanical and other novelties, the most notable of which were the following:

Maschmayer's T-Square; a movable blade square that can be clamped and held firmly in any position by means of thumb-screw, which draws a cone attached to the blade into a corresponding socket let into the head, and also lifts it out again when the blade is to be removed. This device was left for exhibition by Mr. L. G. Carr, of Philadelphia.

A similar device, of wood, with tapering blade, accomplishing the same object by substantially the same means, was also exhibited, as the design of Mr. William H. Thorne, Director of the Drawing School of the Institute.

Reed's Sectional Non-conducting Covering for Steam Pipes, Boilers and Water Pipes was shown in several forms. This covering is formed of compact felt represented to be made of the pulp of woolen rags. It is made in 3-feet sections, to fit any sized pipe, and in sheets for boilers, steam drums, etc., according to their size and shape. A saw cut is made the entire length of these sections, so that they may be forced open and sprung upon the pipe, and when in place the seam is fastened with copper staples. In making joints for a bend the sections are sawed off at the proper angle, and the edges of the joint attached as above. The covering is lined interiorly with asbestos, when desired; or an air space is provided, by using sections of larger diameter than the pipe to be covered, and supporting the ends of the sections on collars surrounding the pipe at suitable distances. Exhibited by Messrs. Bowen & Martin, of Philadelphia.

A number of specimens of Celluloid Stereotypes, consisting of

plates of type, engravings, and of impressions of natural objects, such as ferns and leaves, and of delicate fabrics, such as lace, were shown and described. They are intended as a substitute for the metal electrotypes and stereotypes now commonly used. The celluloid surface is represented to be well adapted for use in printing, on account of its hardness, toughness and elasticity. It is said to possess great wearing qualities and powers of resistance, and to be unaffected by acids, alkalies or other chemicals contained in printing inks, so that the plates can be employed with the most delicate shades of colored inks. Other advantages claimed for it are its ability to reproduce the finest lines of a cut or the finest type with accuracy, and its extreme lightness, which will be appreciated where large quantities of printing plates require to be handled and stored.

Wooden Type with Celluloid Face, of various sizes and styles, were shown. These are introduced as a superior substitute for wooden type. These novelties were exhibited by the Celluloid Stereotype Company, New York.

Several samples of mechanical lamps, of improved construction, with fixtures, were shown. They were adapted to burn petroleum or heavy animal oils without a chimney. In the petroleum lamps a blower, actuated by clock-work suitably disposed in the stem of the lamp, furnishes the air supply to the flame. In the lamp adapted for the animal oils the mechanism performs the double duty of furnishing the air supply and of delivering the oil to the wick tube by means of a pump. These were exhibited by the Hitchcock Lamp Company, Watertown, N. Y.

Samples of Cassava, and of products (starch, glucose, etc.) obtained from it were shown. The plant is represented to grow in great quantity in Florida, and it is claimed to be admirably adapted for the manufacture of glucose. The specimens were exhibited by Mr. Frank Higel.

A convenient Developing Lantern, for use in dry plate photography, was shown. It consists substantially of a rectangular tin box, with draught openings at top, and provided with a petroleum lamp, which can be rotated back and forth to face three sides of the rectangle. One face is provided with ruby glass for developing, and with a hood that can be drawn down to protect the eyes. A second face is furnished with a white porcelain pane, and the third with a plain glass window. The latter two are provided with doors, and are

designed respectively for examining the picture, and for printing by contact. This lantern was exhibited by the designer, Mr. John Carbutt, Philadelphia.

A very novel apparatus, in the form of an Opera Glass, that can be converted in a few minutes into a photographic apparatus, was also shown. It consisted of a complete dry plate outfit, adapted to an opera glass case. A matched pair of lenses (one having an instantaneous shutter) are quickly substituted in place of the usual eye pieces of the opera or field glass. The object glass of one tube is replaced by a plate of ground glass for focussing on, while in place of the object glass of the other tube a dry plate holder is easily attached. These changes have turned the opera glass into a photographic apparatus. It can then be directed towards the person or object to be photographed, and when the image is properly focussed on the ground glass the shutter on the other tube is sprung, and the picture is taken. A rolling spring screen then covers the sensitive plate, and it is transferred to the "dark chamber." This consists of a cylinder of black cloth, like a muff, into which the hands can be inserted, and which fits tightly about the wrists by means of elastic bands at both ends. In this the plate is removed and wrapped up, and another plate inserted in the holder for the next picture; the plate may be left until it can be conveniently developed at some future time. The apparatus is adapted to the use of tourists and detectives, and is made by R. & C. Avizard, Paris. It was exhibited by Mr. W. M. McAllister, Philadelphia.

The Norton Door Lock and Spring was described. It consists of a cylinder, piston, spring and adjustable valve. It is provided with two arms or levers, one of which is attached to the top of the door, the cylinder being connected with it by a hinged joint, and the other to the frame over the same. The spring furnishes the power necessary to close the door, and the valve, which can be adjusted to suit each particular case, provides an air cushion for the piston, thus closing the door quietly. This device was exhibited by H. A. Berry, of Philadelphia.

An Insertable Circular Saw Tooth, that can be attached to the saw plate by means of a key working in a wedge-shaped slot, and removed by pushing back the key, was shown. It was exhibited by Mr. A. J. Barrett.

Mr. G. Morgan Eldridge exhibited a model of Wilson P. Dodson's